Analysis of classroom practices from the knowledge point of view: how to characterize them and relate them to students' performances

Análise das práticas de sala de aula a partir do ponto de vista do conhecimento: como caracterizá-los e relacioná-los ao desempenho dos alunos

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Summary

This paper deals with the relationships between classroom and students' acquisitions. Firstly, we analyse the approaches taken by most of these studies where causality is established between the classrooms, viewed as opportunities to learn and the students' performances. Then we present our approach based on the didactic theory of joint actions of teaching and learning and the associated methodology. This approach is illustrated drawing on the comparison of two physics classrooms (grade 10) during a physics teaching mechanics sequence. Relationships between these classroom practices and the students' performances are established. In conclusion the comparison between the didactic approach and the others shows that the main difference is on the way of viewing classroom teaching: it is focused on the evolution of the classroom group over time from the perspective of the meaning c onstruction of the taught topic more than on classroom situations considered as a learning environments during a session.

Keywords: learning, teaching, classroom, joint action, physics

Resumo

Este trabalho aborda as relações entre a sala de aula e as aquisições dos alunos. Em primeiro lugar, analisamos as abordagens trazidas pelos estudos onde a causalidade é estabelecida entre as salas de aula, vistas como oportunidades para aprender, e a performance dos alunos. Em seguida, apresentamos nossa abordagem baseada na teoria didática das ações conjuntas de ensino e aprendizagem e da metodologia associada.

Essa abordagem é ilustrada com base na comparação de duas aulas de física (grau 10) durante uma seqüência de ensino de física mecânica. As relações entre essas práticas em sala de aula e os desempenhos dos alunos são estabelecidas. Em conclusão, a comparação entre a abordagem didática e os outros revela que a principal diferença está na maneira de ensinar em sala de aula. Esta abordagem é focada na evolução do grupo em sala de aula ao longo do tempo, a partir da perspectiva da construção do sentido do tópico ensinado mais em situações de sala de aula considerada como um ambiente de aprendizagem durante a sessão.

Palavras-chave: aprendizagem, ensino, sala de aula, ação conjunta, física.

The question of the relationships between classroom and students' acquisitions is still open (Hiebert & al., 2003; Roth & al., 2006; Hugener et al., 2009). However aiming at establishing such relations is not new. In this paper, we situate studies most often done at statistical level dealing with this question, then we introduce a case study to show another possible approach.

Approaches of classroom in terms of learning environments

Whatever the perspective, investigating classroom necessitates collecting information on classroom. The main types of methods can be classified into three broad categories (Dessus, 2007):

> "1) use of trained observers coding perceived events (sometimes called low inference measures); 2) questionnaires collecting teachers and students opinions on the class; 3) use of ethnographic methods." (p. 103).

For us, the first two categories are based on similar theoretical approaches of classroom associated to quantitative statistical approaches. Fraser, in his chapter of the International handbook of science education (1998) reviews these approaches that consist of:

> "conceptualising, assessing and investigating the determinants and effects of social and psychological aspects of the learning environments of classrooms and schools." (p. 527).

Further he develops the theoretical point of view:

> "both the environment and its interaction with *personal characteristics* of the individual are potent determinants of human behavior." (Fraser, 1998, p.528, our emphasis)

More generally, these approaches exemplify the way of considering classrooms or more generally learning environments with a *causal perspective based on views on learning*. The question is to specify the determinants that affect student's learning. These determinants depend on the methods, direct classroom observation or students' and teacher' questionnaires. For example in the case of classroom observations, the famous "Flanders grid" (FIAC: Flanders Interaction Analysis Categories, 1976) includes seven categories of teacher talking, and two of the student talking; the observer codes them each 5 seconds. However whatever the methods, there are *categories* which can be structured in scale and items for each scale which are *a priori fixed according to the* *theoretical view of learning*. In other terms the classroom viewed as a learning environment is modelled in terms of categories or of their patterns or clusters. These sets of categories are supposed to be determinants of students' learning.

Analysis of TIMMS video projects in mathematics and science

More recently, TIMSS video studies in mathematics and in science (Hiebert et al, 2003; Roth & al. 2006) introduce a new approach of investigating classrooms with a representative sample of videotaped lessons of mathematics and science in several countries consisting of one lesson by teacher. They take lesson as their unit of analysis. In TIMSS 1999 studies in mathematics the overriding goal is:

> "to *describe aspects of teaching* that appear to be designed to *influence* students' learning opportunities." (our emphasis, p.11).

Three aspects of teaching, are considered as involving learning opportunities:

> "(1) the way lessons were organized or, said another way, the way the learning environment was structured; (2) the nature of the content of the lessons; and (3) the instructional practices, or ways in which the content was worked on during the lessons." (p.11).

In the case of science, the main research question is: What *opportunities did the lesson provide for students to learn scienc*e? The researchers also considered three main aspects: (1) Teacher actions in terms of instructional organization; (2) science content; (3) students' actions, or what opportunities did students have to participate in science learning activities? For science content aspect, the sub-aspects taken into account show the detailed analysis of knowledge involved in the lessons: the disciplines and topics, the types of knowledge, the source of the content, how much science content, the coherence and challenge of the content, the types of evidence, which types of evidence support content ideas; and the multiple sources of evidence. This is in line with their emphasis on the importance of:

> "capturing *aspects* of all of Schwab's four commonplaces of teaching — the teacher, the learners, the subject matter, and the social milieu …" (Roth et al. 2006, p.4).

Both TIMSS 1999 video studies in mathematics and science recognize that:

> [their] "analysis is limited to *observable features* related to the teacher, the students, and the science content which are then used to describe *country patterns of teaching*." (Roth et al. 2006, p.5, our emphasis)

In their analyses, due to their data, both TIMSS video projects *involve the content only at a metal level* like the type of problems in mathematics or the type of knowledge (canonical, procedural, everyday life, …) in science. *The content itself is not categorized* since each lesson can be on a different subject.

These TIMSS 1999 video approaches share with the previous ones similarities and differences. All these approaches considered that classroom teaching (or learning environment) influences students' learning and that classroom teaching is *only described in terms of fixed categories defined before coding video for statistical analyses*. TIMSS 1999 video differs from the previous approach in several respects; in TIMSS video the researchers, in particular in science, considered teaching in a more global view than the previous trends and take into account some aspects of the content. The development of categories was done after data collection and was carried out by an international team; in the case of TIMSS science:

> "[They] discussed coding ideas, created code definitions, wrote a coding manual, gathered examples and practice materials, designed a coder training program, trained coders and established reliability, organized quality control measures, consulted on difficult coding decisions, and managed the analyses and write-up of the data." (Roth et al. 2006, p. 10)

This process of developing categories shows that the global framework of learning opportunities is fixed at the beginning. However the specific aspects to code can be empirically determined. The large sample characteristics, the huge number of lessons, the different languages and cultures, etc. play a role in this determination of categories. This process is possible because of the specificity of video data that in particular allows the researchers to view and review video extracts and to select some of them to exemplify each category..

Recent studies on comparing teaching in science and in mathematics, mainly done in Germany, also involve video of lessons at a large scale (Brückmann & al., 2007; Seidel & Prenzel, 2006, Fisher, Duit, & Labudde, 2005; Hugener et al., 2009). These studies are more theoretically oriented than the video TIMSS studies to the extent that their method is not only oriented towards the "sight structures" that is by taking into account observable features, but also they focus "more strongly on the underlying deep structure of teaching and learning processes" (Hugener & al. 2009, p.68). What do they mean by deep structure? This structure is based on the assessment of "the extent to which the learners are involved in demanding processes of problem-solving and understanding." (p. 68).

Like the first trend, in this last approach, the *classroom analysis is determined by the learning view* like the necessity of being self-active, self-regulated, cumulative and the situated construction of knowledge. Then, they relate these views on learning to teaching:

> "The likelihood of cognitive activation increases *if the teacher links* new content to prior knowledge, *confronts* the students with challenging tasks, different ideas, positions and interpretations, and *stimulates* the students to share and compare their thoughts, ideas, concepts and solution methods, and also *if the students reflect* upon their own learning […]. (ibid, p.68, our emphasis).

These relationships between learning and teaching lead them to elaborate observable features which are related to a deeper structure of teaching.

This last approach is in the same line as the previous research studies to the extent that classroom instruction is characterized in terms of *categories derived from learning view*, and which can be combined in several ways to obtain teaching patterns related to students' learning and then to students' performances.

Up to now, these types of studies do not obtain clear results on the relationships between the classroom, characterized in terms of variables derived from learning views, and students' acquisitions:

> "Teaching patterns describing the ''sight structures'' (Seidel & Prenzel, 2006) of teaching and learning processes *do not seem to have any impact* on mathematical

> achievement measured as a short-term effect. […] The author can hypothesize that the deep structure features of instructional quality (Reusser, 2001, 2006) need to be taken into greater consideration for future investigations." (Hugener, 2009, p. 75- 76)

Hiebert & al. (2003) obtain the same results:

> "There are no simple or easy stories to tell about eighth-grade mathematics teaching from the TIMSS 1999 Video Study results. More than anything, the findings of this study expand the discussion of teaching by underscoring its *complexity*. One thing is clear however: *the countries that show high levels of achievement on TIMSS do not all use teaching methods that combine and emphasize features in the same way*. Different methods of mathematics teaching can be associated with high scores on international achievement tests." (p. 149). (our emphasis).

TIMSS 1999 science study proposes some trends for the learning opportunities emphasizing the importance of the high content standards and of the consistent instructional approach but with great cautious saying that different trends could be found with other data (Roth et al., 2006).

On the reverse, TIMSS 1999 approaches show that this characterization of classroom teaching *allows researchers to differentiate lessons*. In particular TIMSS video studies present different characteristics of the lessons according to the country. Even if there are some discussions about the relative importance of the differences inside a country in comparison to those between countries, the results confirm the relevance of this approach to differentiate the types of lessons according to the chosen variables which are associated to observable events.

In the next part we present our approach in situating it in comparison to those presented above. We introduce our research questions and our theoretical approach before presenting our results on classroom practices and on students' performances. Then we show how we relate classroom practices and students' performances. In conclusion we discuss the differences between our approach and those presented in the above part.

Research questions

Our research questions are at two levels. The main research question is to compare the basic hypotheses and the methodology to study the relationships between classroom teaching practices and students' performances in several approaches. To study this question we compare the basis hypotheses and methodologies, the paradigm behind the approaches of studies like TIMSS video 1999 and our own study. Our own study is a case study based on the observation of two classes in France; then our intention is not to compare the results themselves but the theoretical approaches. Thus a second question is related to our own study that we call "case study": how relating teaching practices and students' performances? We present it after introducing the theoretical framework, the methodology and the type of results.

Our theoretical approach: a didactic framework for the "case study"

The global approach is to characterize classroom practices with a comprehensive perspective in a first step and only in a second step to analyse the students' performances in order to establish relationships between them. Classroom is approached with a didactic perspective and is considered as a complex system which necessitates several scales of analysis. We do not develop the part relative to test questionnaires.

Didactic theory of joint action

In this theory, the main object of study is the classroom viewed as a community of practice where the didactic action involves *two joint actions*: *teaching and learning* (Mercier, Schubauer-Leoni & Sensevy 2002). For Sensevy (2007) this statement is taken as a *fact*:

> "Let us take any didactic act, in each teacher's action, the student has a space, even tiny, and there is the same thing for each student's action. (p.15)

The two joint actions, teaching and learning are produced along duration within the triple didactic relationship between knowledge, teacher and students. (Let us note that Roth et al. (2006) in TIMSS 1999 video science also use the didactic triangle.) These joint actions are based on *communication oriented towards achieving the instructional goal* given by society: the students' acquisition of *the knowledge* decided by the society (official instruction, curriculum). This is due to the institutional role of the classroom, which is a response to the social demand to educate young people. This view of communication oriented by knowledge is developed with the idea of *transactions*. This idea is very coherent with that of joint action: *a transaction of which finality is knowledge*. These considerations lead us to investigate *the didactic action and its evolution within the teaching time by focusing on knowledge in the classroom and its progression* or in other terms by focusing on the evolution of knowledge involved in the transactions. Three aspects are taken: (1) who (teacher, students) introduce(s) and/or deal(s) with knowledge; (2) what is the knowledge involved; (3) in what situations (material and communicative) the transactions take place. Another important component of the classroom, which accounts for the whole classroom practice (or the whole didactic action), is about the reciprocal expectations that the teacher and the students may have. This component has been introduced by Brousseau (1998) who called it *didactic contract*. This contract forms a system of norms, some of which are generic and will be lasting, and others are specific to elements of knowledge and need to be redefined with the introduction of new elements. For example, after the teacher has introduced the concept of force, his/her expectations of the students' interpretations of material situations will be different from before. The didactic contract is deeply linked with knowledge transaction.

Thus classroom is investigated in terms of the didactic contract and three characteristics relative to knowledge considered as the object of transactions. More specifically, three concepts are proposed: chronogenesis, topogenesis, mesogenesis. *Chronogenesis* accounts for the development of knowledge during teaching and involves a relationship between knowledge and time. *Topogenesis*, means the places of knowledge in the classroom; that is, which actors take responsibility for introducing/using elements of knowledge, and to what extent his/her responsibility is recognized by the class. *Mesogenesis* is related to the "milieu," that is the social and material components with which actors construct knowledge and its meaning (Brousseau, 1998; Chevallard, 1991, 1999; Mercier et al., 2002).

The concepts of chrono-, topo-, mesogenesis and didactic contract *characterize class-level phenomena* and not the level of the learner or the teacher as individuals. They allow to study *classroom as a group* and also to analyse individual student contribution to the classroom life.

The knowledge involved in a classroom should be situated in relation to the official curriculum and to the disciplinary knowledge. Following Chevallard (1991), there is a transposition process from the disciplinary knowledge to the knowledge at stake in the curriculum and another transposition from the curriculum to the classroom knowledge. The basic idea of this theory is that the meaning of knowledge depends on the group where it is involved. *Consequently the knowledge involved in two classrooms at the same level and with the same teacher is different because the groups are different.* We call the knowledge involved in a classroom the taught knowledge.

Scales of analysis

The complexity of the classroom as a system has led us to use several scales or levels of analysis. We follow Lemke (2001) on the idea that a very detailed analysis at a micro level does not allow researchers to structure analysis at a higher level:

> "Activities at higher levels of organization are emergent, their functions cannot be defined at lower scales, but only in relation to still higher ones. [...] Going "up" we know the units, but we know neither the patterns of organization nor the properties of the emergent higher-level phenomena" (p. 25).

To reconstruct the taught knowledge we take three scales — macro-, meso- and microscopic — which include both time and granularity of knowledge.

Macroscopic scale

This scale concerns the whole teaching sequence. The macro-analysis gives the conceptual structuring of the sequence in a chronological order but without duration. It also gives the main invariant elements of the didactic contract, in particular the norms established in a classroom (Malkoun, 2007).

Mesoscopic scale

At the meso-scale, due to our approach, *we have chosen a thematic analysis* in order to keep the *meaning* of the 'taught knowledge' involved in the classroom according to the teacher's meaning or more generally the meaning that a person who knows the discipline and the official curriculum would give. Structuring in themes is based on a thematic coherence and on a discourse analysis; most of the time there are discourse markers of introduction and conclusion (Cross & al., 2009). The theme is the *mesoscopic unit of analysis*; this unit that structures a teaching session can have different durations from a few minutes to more than half an hour. Its delimitation depends on knowledge and communication. The title of a theme represents the theme content, its formulation should be as close as possible of the effective discourse. The words used in the title should be *effectively* involved in the classroom discourse. The theme plays two roles: decomposing the classroom discourse into units in a chronological order (see figure 2) and investigating how elements of knowledge are introduced, by which actors, with what supports (experiment, text, etc.). This unit is particularly relevant to investigate the students' and teacher's responsibility for knowledge development and display (topogenesis) (Malkoun, 2007; Mortimer et al., 2007; Tiberghien & Malkoun, 2009).

Microscopic scale

At the micro scale we have chosen two types of analysis: facets and epistemic tasks. Facets correspond to small elements of knowledge. Our way of using facets comes from Minstrell (1992), Galili and Hazan (2000), and Küçüközer (2005) but our use differs in particular to the extent that facets are referents in discursive production analysis. This microscopic scale is also important to understand the communicative processes in particular the transactions (Marlot, 2008).

Regarding the epistemic tasks, we investigated how the classroom discourse involves thought processes used in understanding the material world. To define these processes we have adapted the epistemic tasks proposed by Ohlsson (1996) on the basis of our epistemological approach of modelling in physics teaching so that these tasks are related to understanding the material world (Sensevey et al., 2008).

Classroom model

With this theoretical approach associated to a methodology of analysis, we construct a model of the classroom practices. This model aims at accounting for the meaning of teacher's and students' actions from the knowledge point of view in terms of chrono, topo and mesogenesis; in fact our modelling is mainly focused on the chrono and topogenesis, and the mesogenesis is often implicit. This model consists of several representations of classroom at different scales, and of narratives. We do not present our methodology as such but we introduce it with the results of our classroom analyses (see Tiberghien, Makoun & Seck, 2008; Tiberghien & Malkoun, 2009).

Other analyses of classroom in terms of joint actions also provide an understanding of how a class works, and in particular lead to investigate "ordinary teaching" (Marlot, 2008; Ligozat, 2008). Such modelling allows the researchers to better understand the didactic processes in the classroom.

Learning views

The perspective is socio constructivist to the extent that, the classroom is considered as a community of practices in which teacher and students act and construct meanings on a social plane and then possibly on a personal plane (Vygotki, 1934/1997). The nature, the content of the classroom discourse, the way it is constructed, in particular the contribution of the participants, the associated tasks play a role in the meaning construction by each actor of the class and by the class group. More concretely, particularly with the concept of topogenesis, participants' contributions to the meaning construction are specifically analysed directly at meso level and with the epistemic tasks at micro level as presented below; the role of semiotic, in particular the importance of formal representations used in the teaching sequence are also taken into account at meso and micro levels as presented below.

However, we also take into account what students "take away" and not only their participation to classroom practice (Ford & Forman, 2006). To analyse what students "take away" we use written test questionnaires that can be considered as coming under a cognitivist approach.

Moreover, our position on learning has been reinforced with a series of research studies in science and mathematics education. We have focused on studies relating to students' learning in the classroom during a teaching sequence. These studies deal with the individual student's learning pathway (Psillos & Kariotogou, 1999, Küçuközer, 2000, 2005; Givry, 2003; Givry and Roth, 2006). From these results, we deduce that learning pathway follows neither a rational decomposition of disciplinary knowledge nor the order of introduction of taught knowledge in the classroom. The pathway towards understanding the relationships between concepts does not necessarily start by understanding each concept; the learner's construction of his/her own understanding may involve simultaneously this relationship and each one of its terms. We also deduce that learning can often consist in relating small elements of knowledge. In particular, learning can consist in relating an element of knowledge involved in the taught knowledge to a set of elements of knowledge already acquired, that is not necessarily the set in which this element has been inserted in the taught knowledge. Therefore the relations constructed by students between small elements of knowledge can be different from those involved in the taught knowledge and students can acquire elements of the taught knowledge without an overall conceptual understanding. This hypothesis has methodological consequences to the extent that it leads to break down the discourse at a microscopic level. The notion of facets introduced by Minstrell (1992) opens the door to an analysis at *a small granularity of knowledge without limiting the analysis to this level*.

Our leaning views also include a position related to the epistemological choice on modelling in physics. This choice states that relating a material situation (objects/events world) to the physics conceptual framework (theories/models world) to interpret, predict experimental facts, or to develop theoretical components, etc. is very difficult. Consequently to favour students' understanding we state that these two worlds should be explicitly differentiated including with language. For example in the case of mechanics, force is a physics concept and then should not be used to describe a material situation modelled by mechanics theoretical framework, another word should be introduced. The term "action" is chosen to describe the events for example in the case of contact between two objects, a pen on a table, we say: the table acts on the pen and the pen acts on the table. The verb "to act" can also be replaced by a more specific verbs like to push, to pull, to attract, etc. (Tiberghien et al., 2009). The modelling activity analysis can be carried out at micro level with the epistemic tasks that include specific thought processes of relations between the two facts, events and the theoretical components as presented below.

This position on knowledge supposes the importance of prior knowledge. It also, but more implicitly, supposes the importance of the situation in which the knowledge is introduced because the learner constructs relations between a new element of knowledge and his/her prior elements of knowledge according to his/her overall understanding of the situation.

Teaching, learning and performances

Our position on learning has a strong influence on the methodology to analyse classroom practices, in particular the specific methods at micro levels with facets, and epistemic tasks. However it is the joint action theory that guides this study on classroom practices. The analyses in terms of chrono, topo, and mesogenesis are done at three scales. In particular at a fine granularity of knowledge 'to catch' small elements of knowledge (facets) and the associated thinking processes (epistemic tasks), and at meso and macro scales 'to catch' the way the small elements of knowledge are *introduced* *and re-used*, the *meaning they have in the situation*. Therefore a special attention should be given to the *relationships between the analyses at different scales*.

The students' performances are evaluated with a test questionnaire given before and after the teaching sequence. The questions of the test questionnaire were designed on the basis of a research study on students' assessment during the SESAMES teaching sequence. The questions were carefully selected and adapted in order to be relevant for students who do not follow this sequence (Coulaud, 2005). Most of these questions start by a description of a material situation and ask for interpretations in conceptual terms (see examples figures 8 and 9), however some questions start from theoretical proposals and ask if these proposals are compatible with material situations or ask to check a definition of a concept. Each question is analysed in terms of small elements of knowledge (facets) at micro level or in terms of a more global set of knowledge and processes at a larger granularity of knowledge. Then relationships are first established with the analysis of classroom at the level of small elements of knowledge and extended at higher levels in order to take into account the meanings of students' and teacher's actions involved in the teaching situations.

In conclusion, a specific research question for this study on classroom comparisons can be formulated: where and how elements and sets of knowledge are involved in classroom practices and with what meanings? What elements of knowledge and processes are involved in the test-questionnaires? Are there relationships between these models of classroom practices and of the students' performances?

Collected data for the "case study"

We collected two types of data.

1. Two physics classrooms at grade 10 were videotaped during the part of mechanics focused on dynamics. In one class, the teacher followed a teaching sequence elaborated in the context of a research-based design project (SESAMES, 2007-2010), and in the other class the teacher used his own teaching sequence. In the following, the first class is called class 1 or Sesames-seq, and the other is called class 2 or Teach-seq. The teachers of these two classes have more than 20 years of experience. The two schools are situated in middle-class areas in France.

In each class, two cameras were used, one focused on the teacher and a part of the class and the other one focused on two students (the same students during the whole teaching sequence) and a part of the class.

2. Test-questionnaires were given about one month before and one month after the teaching sequence on mechanics in 19 classes: a set of 9 classes where the teachers used their own sequence (Teach-seq) and a set of 10 classes where the teachers used the SESAMES sequence in mechanics (Sesames-seq). The two videotaped classrooms were part of each set.

Analysis of classrooms

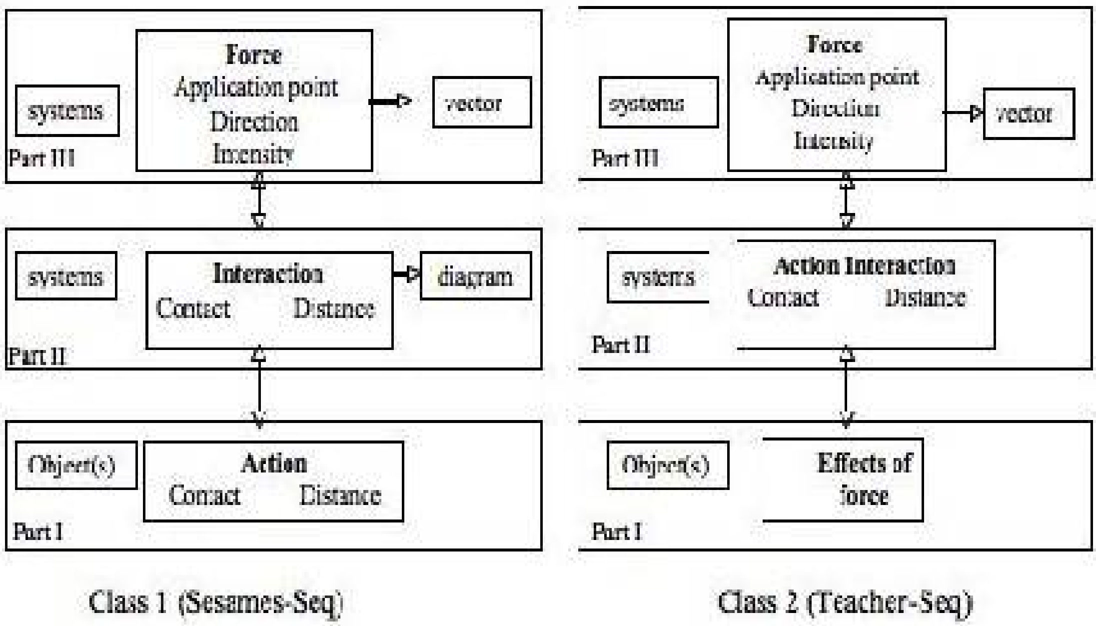
This analysis first presents the evolution of the taught knowledge during the teaching sequences at three scales, the chronogenesis, and then gives the way the taught knowledge is involved, the thinking process with which elements of knowledge are involved and the responsibility vis a vis knowledge of the teacher and the students, the topogenesis.

Chronogenesis of the two classes

The analyses of knowledge evolution during the mechanics teaching sequence has been carried out at three scales, we present them successively.

Reconstruction on the macro scale: the conceptual structure

Figure 1 presents the conceptual structure of the two sequences. The main difference is in part I. In class 1, due to the epistemological choices of the SESAMES group on modelling (Tiberghien & Malkoun, 2009), the differentiation between the concepts and the objects / events of the material world leads the designers to avoid the idea of "effects of force". As a matter of fact, they decided that in the teaching sequence the word "force" only means the physics concept and not the everyday meaning. Therefore, they introduced the word "action" to designate the event: an object acts upon another one when they are in contact. Thus the notion of action is introduced first in the SESAMES sequence whereas it is introduced with the concept of interaction, in the part II of the teacher-sequence. In the two classes the parts III are similar at this macro level of analysis.



Reconstruction on the meso-scale: themes

As we have introduced in the methodology, at the meso level, our analysis is thematic to account for the meaning of the classroom discourse. Figure 2 presents a part of the series of themes in the two classes; it allows the comparison of the succession of themes (Malkoun, 2007). Classes 1 and 2 start with different concepts as shown in the macro analysis, class 1 with action and class 2 with the effects of force. It also appears that class 1 has several themes corresponding to a single one in class 2 (Figure 2, theme 2, session 2 of class 2 'modelling actions by the forces' is associated to four themes in class 1). The succession of themes is a *representation* of the chronogenesis of the two classes at meso-scale during the whole teaching sequence. It relates meso and macro scales.

Session	Time (min)	Themes in class 1	Themes in class 2	Time (min)	Session
		………………………			
S 2	6:13	1. Graph representation	(other topic)		
	13:35	2. Interactions for various situations	1. Effects of force on the motion of a object	18	S I
		3. Situations for chosen systems in interactions	2. *Interactions*		
	1:25	4. Introduction of the general theme of the notion of force	2a. Interactions = A acts on B then B acts on A	14:53	
	14:44	5. Determination of phases of motion of an object, direction of action on this object, variation of velocity	2b. Interactions at distance and contact interactions	4:19	
	10:41	6. Analysis of interactions for different phases of motion of an object (case of a medicine-ball)	1 Revision of interactions	1:31	S II
	4:41	7. Introduction of the force and its vector representation and of the principle of reciprocal actions	2. Modelling actions by the forces (representation and measurement of forces)	34:00	
	9:23	8. Using (exercising) force and its vector representation from interactions (use of the full model of interactions)	3. Force and mass	10:26	
S 3	5:14	1. Interactions: relations between a symbolic representation and one or several material situations	4. Lists of forces which compensate or not according to the motion	44:48	
	10:10	2. Representation of force modelling an interaction (not length of vectors)	…..		S IV
	30:31	3. Representation of force modelling a moving object			

Reconstruction on the micro scale: continuity

The second type of analysis is carried out in terms of facets. A facet is a simple sentence which means a component of a theory, a concept, a procedure, an epistemological statement, a description, a skill, or more generally any component of knowledge whatever it is, scientific, everyday, etc. The set of facets constitutes the reference to analyse the classroom discourse at the micro-scale level.

The set of facets that we have created is based on an analysis of the 'knowledge to be taught' (curriculum, textbooks) and on the classroom's productions in an iterative approach. Here is an example of the analysis of the classroom discourse in terms of facets. This example comes from a situation in class 1 during the part I of the sequence on dynamics, theme 2 of session 2 (figure 2). The students had to make some exercises and the correction takes place with the whole class. The transcription extract corresponds to the part of the exercise given in figure 3.

Information

Before this correction in the previous session, the students were introduced to a "model" involving a graphic representation where an object (the notion of system is introduced later on) is represented by an ellipse and the action of contact between two objects by a full arrow, the action at distance by a dotted arrow.

Extract of the statement of exercises

With the help of the model of interactions, draw the diagram system-interactions describing the following situations. The underlined word indicates the object corresponding to the system considered.

1. a) An object put down on a table.
   b) A table on which an object is put down.

Figure 3: information on what the students already know on the graphic representation before doing the exercises and extract of the statement of the exercises

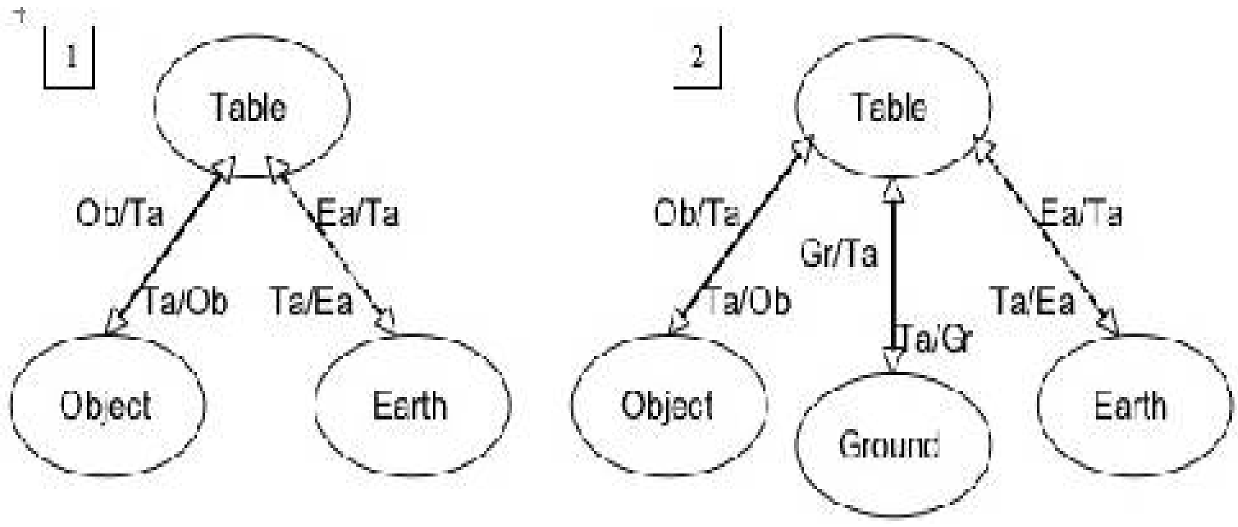


Figure 4: part 1: student's solution, part 2: correct solution

	(In this extract E and M are for students and T is for Teacher. This extract follows a classroom discussion with debate on the difference between the ground and the Earth, the solutions in figure 4 are on the blackboard).
1. T	a table on which an object is put on
[several exchanges between the teacher and several students]	
2. T	the ground and the Earth is it the same thing?
3. E	no
4. T	the action of the Earth on the table how do you imagine it? What does the table tend to do?
5. M	(inaud.) a force
6. T	it is an action that attracts the table towards where?
7. M	mm downwards
….. [Turns 8, 9, 10]	
11. T	what does it tend to, what does it?
12. E	it does not move
13. T	yes it prevents the object from falling that is it prevents the object from sinking into, on the contrary mm how does the ground act on the feet? Does it attract my feet? No on the contrary the ground acts upwards,
….	
15. T	the ground, thus it can be the earth of the garden but even if it is the earth of the garden it is not the Earth as an object. The action of the ground prevents the table from sinking whereas the Earth attracts towards its centre on the contrary

Figure 5: extract of transcription in class 1 during session 2 theme 2 (figure 2)

From our analysis, turns of speech 4 to 7 (Teacher and students) correspond to the facet: "The action of the Earth is always downwards"; turns of speech 4 and 6 also involve the facet: "The Earth always acts on (attracts) the object", and turns of speech 13 and 15 involve the facet: "The action exerted by the Earth and the action exerted by the ground are not the same". It appears that a same exchange can correspond to several facets.

The discourse of the class when the work was done in the whole class was coded in terms of facets by themes. Moreover, in our coding, we distinguish between a "new facet" that corresponds to an element of knowledge introduced for the first time in the class, and a 're-used facet' that corresponds to an element of knowledge already introduced. This way of coding enriches the analysis of chronogenesis. We also group the facets according to the notions or skills, epistemological statements, etc. In this study our way of grouping the facets is mainly oriented by the conceptual analysis of the taught knowledge.

Another way of representing the taught knowledge is to select the facets which are the most reused. It allows us to know which aspects of knowledge are emphasized in a given class.

Groups of conceptual facets and representation	Facets	Class 1 (WC)	Class 2 (WC)
Action - Interaction	When object A is in contact with object B it acts on it	**20**	2
Force - Interaction	When object A is in contact with other objects, it exerts a force on these objects	1	**12**
Motion	The motion of a point is rectilinear when its trajectory is a straight line.	8	14
Representing	Force	**11**	6

Table 1 Number of times some of the most frequent facets are reused in the two classes (Malkoun, 2007) (WC= whole class)

Table 1 confirms the difference between the two classes already observed at macro level, in that action (relative action of a system on another – interaction between two systems) plays an important role in class 1, whereas in class 2, only force (relative force – interaction) is involved. It also shows the importance of representations in class 1. This difference also appears at meso level, for example force vector is involved in several themes (last line figure 2, theme 7, session 3, class 1).

It is also useful to have a representation of when frequent elements of knowledge appear during the teaching sequence, that is in which session and which theme; this representation is given in figure 6 for four facets.

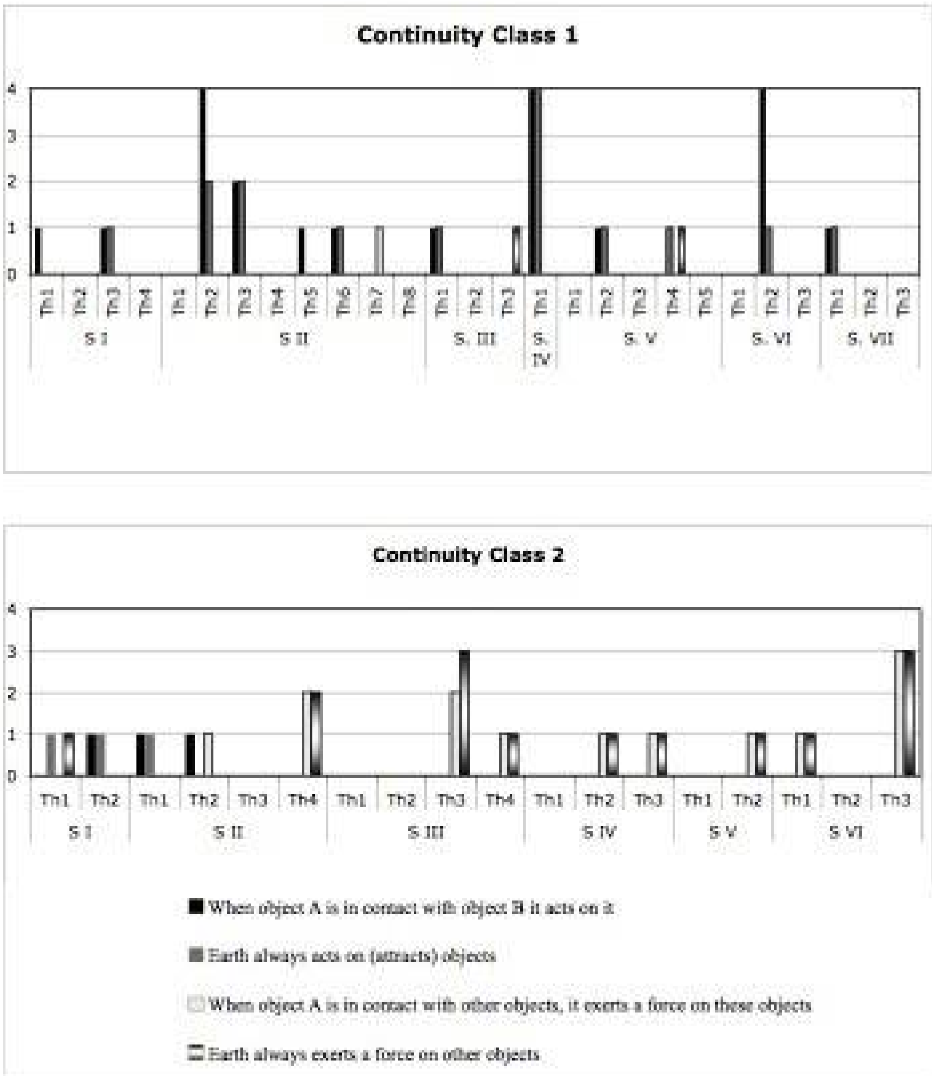


Figure 6 Distribution of the most frequent facets over the duration of the teaching sequence, presented in themes and sessions when the work is done in whole class.

Figure 6 shows that both teachers use similar elements of knowledge during the whole teaching sequence. This analysis also shows *coherence* between the theme and the facets involved, these characteristics could be a sign of experienced teachers.

Representations like that of figure 6 situate events at the micro-scale (an utterance or a verbal interaction corresponding to a facet) on the meso and macro levels of the entire sequence. Thus *facets serve as landmarks in the content of the classroom discourse*. The addition of same facets situated at different time of the teaching sequence gives also indications of the potential of similar meanings in the whole classroom discourse; this is why we call this representation *continuity*. However analysing the meaning of the discourse content corresponding to a facet at a meso scale should be done to confirm these indications.

Topogenesis

Topogenesis accounts for the responsibility of the students and the teacher vis a vis knowledge. To understand it from the video data and the transcription, we use our analyses in terms of the epistemic tasks at micro level and of a narrative at meso level.

We elaborated a series of epistemic tasks that are directly related to our epistemological choice on modelling in physics in relation to our learning hypothesis. A series of tasks deals with processes involved in modelling between the two worlds of objects/events and theories/models. The task "defining" deals with the construction of the theoretical framework of modelling. The task "doing formal operations" deals either with theories/ models or with the relations between the two worlds. The tasks "describing", "selecting", "interpreting", "predicting", "comparing" and "generalizing" can deal with theories/models or material objects/events or bring into play relations between the poles of modelling (theory, model and experimental field). For example it is possible to interpret an event with other events or with concepts, this difference is specified in our coding (to see more detailed analysis see Malkoun, 2007). Other tasks *necessarily bring into play the interactions* between actors of modelling: "explaining", "arguing (argumentation)" and "criticizing / evaluating". These tasks are not exclusive of the previous ones.

In addition, to better situate how these processes are involved in the classroom, in our coding we distinguish which actor (teacher or students) elicits a task or carries it out. This distinction comes from the importance we attach to the responsibility of each actor (teacher or students) towards knowledge. This distinction allows us to identify if there is consistency between what is elicited and what is carried out and whether students meet the teacher's expectations and/or take the responsibility of knowledge. For example in the extract given in figure 5, turn of speech 2, the teacher elicits a comparison and the student in 3 carries out a comparison; the teacher elicits an interpretation at the level of objects/events in 4, 6 and 11, and in 7 and 12 a student carries out the interpretation. Then in turns of speech 13 and 14 the teacher carries out the interpretation in terms of objects/events. Epistemic tasks were systematically coded for the two classes directly from video.

Figure 7 shows that in the two classes, when the work is in whole class, the most elicited and carried out tasks are interpretations between material objects/events and the theory/model. However, the number of elicited tasks by students is lower in class 2 (20) than in class 1 (54). Another important difference is the variety of epistemic tasks in class 1 compared to those in class 2. In class 1 for example, the interpretation between objects/events is a little bit less frequent than the interpretation objects/events - theory/ model whereas in class 2 this type of interpretation is rare. The higher number of formal operations in class 1 is due to the importance of representations (diagram systems-interactions and force vector) whereas in class 2 the teacher does not introduce this diagram for interactions.

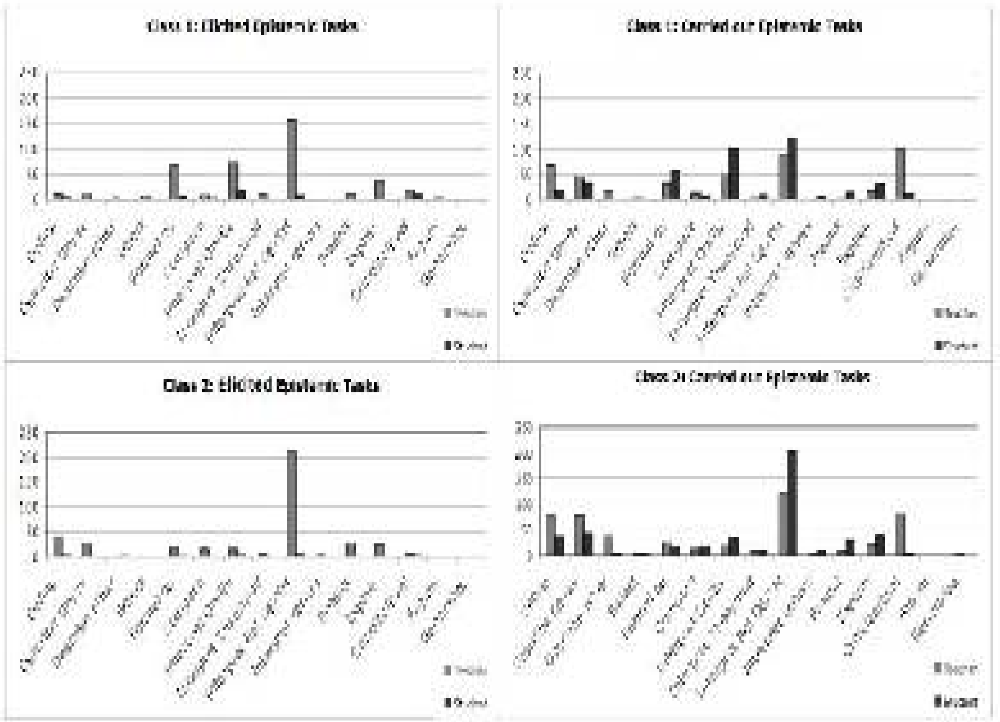


Figure 7: Epistemic Tasks for the whole sequence in classes 1 and 2 when the work is done in whole class. Black is for students and grey for Teacher

Figure 7 also allows us to draw some information for the topogenesis and the didactic contract. In the two classes, when they work in whole class, the teacher elicits more than the students however the teacher carries out the tasks only slightly more than the students. Some tasks are more on the teacher's side like defining, describing, criticizing/ evaluating whereas interpreting and at a much more lower degree predicting are on the students' side. This means that the students contribute to the classroom discourse in particular to interpret. Then globally, we can consider that knowledge responsibility is shared between the teacher and the students even if the teacher has more responsibility. However, this analysis that relates the micro level of the epistemic tasks and the macro level of the whole sequence does not account for the great variation of the way responsibilities are shared in a classroom depending on the situations. An analysis by themes at meso level is necessary.

For the analysis by theme, we mainly use a narrative form as Bruner (1996) suggested:

> "The object of interpretation is understanding, not explanation; its instrument is the analysis of text. *Understanding is the outcome of organizing and contextualizing* essentially contestable, incompletely verifiable proposition in a disciplined way. One of our principal means for doing so is through narrative: by telling a story of what about something is "about." (p.90, our emphasis).

We give a short example of this type of analysis. It comes from the same part where the transcription extract given above to introduce the facets comes from (figure 5), that is theme 2 of session 2 in class 1 (figure 2).

> "The students, who are at the blackboard, make the correction of the exercises and when the diagrams are drawn, in a first step the teacher *reformulates with words the diagram* and the students discuss the proposals, in a second step the teacher asks the student to correct their errors on their notebook. [….]
>
> The use of the diagrams brings out students' difficulties on the difference between the Earth and the ground and on the role of the air. The first difficulty leads the teacher to introduce a new element of knowledge, the direction of the action of one object on another, which, in fact, is planned later on in the teaching sequence. For that element of knowledge, the teacher takes the responsibility of its introduction. On the reverse, the students who make the correction take the responsibility of introducing knowledge in drawing their diagram. The students seated in the classroom take also the responsibility of putting some drawings in question with arguments. Then in this theme, the teacher and the students share the responsibility of dealing with knowledge." (extract from Malkoun, 2007, p.150).

Such a narrative accounts for the situation in its chronological aspects of the *several simultaneous components of the situation,* in particular the content *and* the sharing of responsibility vis a vis knowledge. Whereas our microanalyses differentiate content (themes and facets), thinking process and responsibility of knowledge (elicited and carried out epistemic tasks), the narrative gives an account of all these imbricated aspects and thus gives an account of the meaning of the situation; however the narrative is limited in duration.

We think that the narratives are well adapted to the meso-scale to the extent that this time scale seems particularly relevant to describe and interpret a group life with the size of a class.

Results of the test-questionnaires

The test-questionnaire was designed to test conceptual acquisitions. To illustrate how relationships can be established between the results of the questionnaires and the classroom practices, we selected questions dealing with complex and difficult conceptual relations like the relation between force and motion, and with specific notions where there are differences of students' acquisition in favour of one class or the other (and their corresponding set).

Concepts dealing with relation force-motion

All the studies on conceptions agree that the relationship between force and motion in a situation where an object, when released, continues to move on a support or in the air, is very difficult to acquire even if the teaching sequences take into account this conception (Viennot, 2001).

Two questions for two different units (A and B) assess the acquisition of this component of knowledge (Figures 8 and 9). Note that, for these two questions, the only forces acting on the object (ball thrown upwards or puck thrown horizontally on the ice) are that of the Earth and those of objects with which it maintains contact. So once the ball started at the vertical it continues to go upwards and the main force exerted on it is that of the Earth (its weight) and, if we do not neglect it, that of air. The ball moves up and the resultant of forces acting on it is downwards (its velocity decreases). The studies on conceptions show that a significant proportion of students (even a majority) of all levels "invent" a force exerted on the object that is in the direction of the motion.

UNIT A

A ice hockey player throws a puck. When the puck is thrown, it slides on the ice with a uniform rectilinear motion

…..

Question A.1. Among the forces below, select the force which is exerted on the puck when it slides on the ice

Proposed items to tick:

- weight,

- force exerted by air,

- force in the direction of the motion

…

Question A4. Draw the forces which are exerted on the puck

Figure 8 Statement of unit A of the questionnaire (partial)

item: Force in the direction of the motion (ice hockey puck)	*Before teaching*		*After teaching*	
	Selected	**Not Selected**	Selected	**Not Selected**
Sesames-sequence (N=333)	69	**31**	25	**75**
Teacher-sequence (N=252)	70	**30**	49	**51**
Class 1 (Sesames-sequence) (N=31)	74	**26**	26	**74**
Class 2 (Teacher-sequence) (N=28)	68	**32**	39	**61**

Table 2: Percentage of answers to the question A1, item: force in the direction of motion (right answers: item non selected; in bold) (statement figure 8)

First, these results (table 2) indicate that, before teaching, classes 1 and 2 are identical to the sets to which they belong, while after teaching class 1 behaves almost the same than its set and class 2 a little better. We may consider these two classes have greatly increased even if class 1 is better than class 2 after teaching.

UNIT B

At the beginning of a basketball game the referee takes the ball and throws it upwards to the vertical.

All these questions deal with the case where the ball is moving upwards once the referee has dropped. Among the forces below check those exerted on the ball during this phase:

Question B.1

Items proposed to check if it is considered as true:

- A vertical force exerted upward by the hand of the referee

- A vertical force exerted downwards by the Earth

Figure 9: Statement of unit B of the questionnaire (partial)

Question B.1 **Item: A vertical force exerted upward by the hand of the referee**	Before teaching		After teaching	
	F Mvt	No F	F Mvt	No F
Sesames-sequence (N=333)	89	**11**	60	**40**
Teacher-sequence (N=252)	88	**12**	88	**12**
Class 1 (Sesames-sequence) (N=31)	87	**13**	55	**42**
Class 2 (Teacher-sequence (N=28)	89	**11**	93	**7**

Table 3: Percentage of answers, 'F Mvt' means that the item 'A vertical force exerted upwards by the hand of the referee' is considered as false and 'no F' is considered as true

In this case too, before teaching, the two classes behave as their respective sets, whereas after teaching class 1 is a bit better than its set and class 2 behaves similarly (table 3). Even if, after teaching, class 1 is significantly better than Class 2, less than half the students succeed. At the same time we can consider that this progress is remarkable, since the teacher-sequence classes (of which class 2) have not progressed. These results confirm the difficulty of such an acquisition already well established.

The results of the percentage of students giving a correct answer to the two questions A1 and B1 (figures 8 and 9) are presented in table 4.

Right answer to	- Item "F in the direction of the motion not selected" **and** - No F on the ball after the basketball referee thrown it up
Sesames-sequence (N=333)	**35**
Teacher-sequence (N=252)	**8**
Class 1 (Sesames-sequence) (N=31)	**42**
Class 2 (Teacher-sequence) (N=28)	**3**

Table 4: percentage of correct answers to the two questions A.1 (item 'force in the direction of the motion) and B.1 (item A vertical force exerted upward by the hand of the referee) given tables 2 and 3

These results confirm the difference between the classes 1 and 2 and their corresponding sets concerning the conceptual acquisition, in particular the greater coherence of set "sesame-sequence" and in particular class 1. These results are all the more important that other questions show similar results *on the better coherence* of SESAMES classroom (Malkoun, 2007). They also show that progress is possible but difficult.

Specific notions or concepts and their formulation

In this paper, we selected the specific notion of weight which, for the physicist, is the force exerted by the Earth. In the questionnaire, depending on the questions, the two formulations were used. It appears that the results are not the same according to the formulation; let us note that we did not anticipate these results.

Figures 8, 9 give three questions, the word « weight » is used in the first one and in the second it is asked to represent it as a force (figure 8), the third question (figure 9) uses the expression « force exerted by the Earth ». The results are given table 5a and 5b; table 5c gives the crossing between the second and the third questions to show the role of wording.

Question A.1 for the item: weight	Before teaching	After teaching
Sesames-sequence (N=333)	73	65
Teacher-sequence (N=252)	76	93
Class 1 (Sesames-sequence) (N=31)	74	64
Class 2 (Teacher-sequence) (N=28)	71	100

Table 5a: percentage of answers where the item weight is selected as force exerted on the puck (question 1)

Question A.4 Representation of the weight vector	Before teaching		After teaching	
	All vector rep.	**Correct Rep.**	All vector rep.	**Correct Rep.**
Sesames-sequence (N=333)	55	0	76	**14**
Teacher-sequence (N=252)	48	0	86	**10**
Class 1 (Sesames-sequence) (N=31)	67	0	77	**23**
Class 2 (Teacher-sequence) (N=28)	45	0	85	**7**

Table 5b: percentage of answers giving a vector representation of the weight: all of them and the correct ones

Question A.4 Wording of the weight vector when represented with a notation	After Teaching			
	$F_{system/system}$	Written name	Standard wording (P, R, T)	$F_{p/S}$, F_{weght} $F_{weght/system}$
Sesames-sequence (N=240)	44	10	22	12
Teacher-sequence (N=174)	7	20	61	3
Class 1 (Sesames-sequence) (N=22)	71	4	0	19
Class 2 (Teacher-sequence) (N=22)	14	0	53	14

Table 5c: percentage of answers according to the vector notation associated to the weight vector the percentage are taken on the total of the answers giving a notation to the vector representation (given between parentheses)

The rate of correct answers show that a lower percentage of students in Class 1 (Sesames- sequence) answered correctly the question on the weight exerted on the puck (table 5a). However, surprisingly, the percentage of students drawing the vector of the force exerted by the Earth on the puck (77%) (table 5b) is higher than the percentage of students who ticked the weight (64%) for class 1 contrary to class 2 where 85% of students draw a force whereas 100% of students ticked the weight.

Results of question A4 (table 5c) clearly shows that a majority of students in class 1 uses the notation $F_{system/system}$ (71%) whereas students of class 2 use more various notations.

For questions B1, item “a vertical force exerted downwards by the Earth”, the two sets and each class show good results (100% class 1 and 89% class 2, and for the two sets respectively 92% and 86%). However when the wording is in terms of weight the results of class 1 are lower than for the wording force exerted by the Earth, whereas for class 2 the influence of wording is not clear. In fact we did not anticipate this result.

Concerning the notation of forces and their vector representation the answers show that in the Sesames-sequence set and in particular in class 1, a greater number of students has acquired the use of a standard notation: $F_{X/Y}$. Similarly we may consider that they have acquired the language expression "force exerted by the system A (or object) on the system B" without having the same control of the standard names of forces especially the weight and we find the same type of results for the more frequent use of standard names: reaction, tension in the "teacher-sequence classes".

In conclusion, these results show that the correct answers of a majority of students in both classes have increased significantly for much of the questions and that *wording the name of the forces has an influence on students' performances*.

Relationships between the results of the questions and the classroom practices

We start with the questionnaire by analysing each question to determine the elements of knowledge necessary to answer them. This analysis is done at micro and meso levels. At micro level the analysis is done with facets. Then when it is relevant, the difficulty of the question is analysed at more global level; this is the case for questions dealing with relation force-motion presented below.

Facets are the first link, like a thread, between the test questionnaire and the classroom practice. This thread starts from the question analysed in terms of facets and plays the role of pointing the place where the elements of knowledge (facets) may be involved in the classroom actions (mainly the discourse); *facets are landmarks* to focus the analysis of classroom practices at possible relevant places. Then *the meanings*, that the elements of discourse corresponding to facets can have, *should be analysed in their context at meso and macro levels*. Let us note that the epistemic tasks cannot play the role of bridge between the test questionnaire and the classroom practice because they do not discriminate enough, for example interpretation is involved most of the time contrary to the *facets that involve a specific content (whatever it is) and then indicate a specific place in the classroom discourse*.

To present how we established these relationships we take the same order as the results of questionnaires.

Case of concepts dealing with relation force-motion

A first link between the questionnaire and the classroom practice: the facets

The analysis of the two questions (question A1 with the puck, figure 8 and question B1 with the ball launched by the referee, figure 9) in terms of facets shows that to answer them only some facets have to be used, even a single one. The essential facet is: "When an object is in contact with others then it exerts a force on these objects." Two other facets may also be used: "When an object A is in contact with an object B it acts on it (there is contact interaction between A and B)" and "When an object A is not in contact with an object B then it does not exert an action on it." One might wonder why statements as simple as these facets are not used in these questions by a rather important part of the students after teaching. The answer requires a thorough analysis of physics knowledge and of students' knowledge at a more global level. As noted above, this force in the direction of motion proposed by the students (and a large portion of nonphysicists) is a sign of the use of a causal relationship. A motion has a cause, in the case of the ball or the puck it is the throwing by a person. The transition from motionless to motion and therefore the change of velocity should be related to the force exerted by the system "person" from a physics point of view. And as soon as the ball is thrown there is no more action from the person on it. This analysis requires distinguishing two steps in the situation and to have a Newtonian model to relate the motion of the ball and the forces. Thus, it is not enough to know the wording of the facets in question, but it is also necessary to select and use them; *this supposes that these facets are consistent with the vision and understanding of the material world of those who responded*. Therefore to interpret the difference in results between the two classes, beyond the consideration of the use of these facets, we must consider how this analysis of motion has been processed. The analysis requires taking into account not only the evolution of the taught knowledge during the teaching sequence but also the teacher' and students' positions vis-à-vis knowledge, and classroom situations (topogenesis).

Firstly, let us look at the number of times these facets have been used in each classroom (see table 6).

		Class 1 (Sesames-sequence) Whole class	Class 2 (Teacher-sequence) Whole class
Action-Interaction	1- When object A is in contact with object B then it acts (exerts an action on) it (there is contact interaction between A and B)	**21**	**3**
	2- When an object A is not in contact with an object B then it does not act (exert an action) on it.	**3**	**2**
Force	1- When an object A is in contact with other objects then it exerts a force on them.	**1**	**13**
TOTAL		**25**	**18**

Table 6 Number of times where a facet was introduced and re-used in the whole class

It appears that number of facets used in class 1 for the whole class is more important than in class 2 (table 6). Moreover, our analysis during the work in small groups of the teacher's talk with groups increases this tendency very significantly. It means that the meaning of the notions corresponding to these facets may be involved in the themes where the facets were coded, this leads us to analyse these themes in a second time; again facets serve as landmarks.

Meanings involved in classroom practice at the place where facets are

In both classes, the facets relating contact between two objects and action or force are involved in the entire sequence, from the first to the last session (figure 6). To illustrate our analysis we briefly describe how the facet "when an object A is in contact with an object B then it acts (exerts an action) on it (there is contact interaction between A and B)" and the facet "When an object A is in contact with other objects then it exerts a force on them" are involved in each class in relation to the directions of force and of motion. Thus, our analysis is guided by the facets but includes other elements which make sense for the notions in question.

Class 1 (Sesames-sequence): In this class, this facet is introduced in session I during ac activity focused on the idea of action between objects and just after with *a formal model* (diagram systems-interactions) since it is associated with a full arrow which accounts for the contact action (see figure 4). It is used session II in themes 2 and 3 still associated only with the event "contact" and its formal representation (full arrow) whereas in themes 5 and 6, the distinction of the different phases of the motion of a ball when it is launched and caught and the direction of action of the hands are introduced as such with the manipulation of a medicine ball. Let us note that in these themes, the most frequent epistemic tasks are formal operation (using diagram system-interaction and interpretations at the level of objects and events. This epistemic task can be considered *as a way to "see" the material world with physicist eyes*; for example only a physicist describes the situation where an object is put on a table by saying that the object is motionless and in contact with the table (Sensevy et al., 2008). In session IV, the facet is used when the teacher introduces the concept of force. It is still used after the introduction of force (sessions V, VI and VII) in connection with the descriptions of actions to relate them to the force concept. Moreover the importance of graphical representations is clear, students must represent the direction of motion on one hand and the force on the other hand. In the whole sessions, there is a significant importance on the distinction between the meanings of action, force, velocity change, motion, moreover action or force and motion are related, but clearly distinguished. The analysis of classroom at meso level with themes (figure 2) shows that, in class 1, there are several themes concerning the vector representations whereas in class 1 no theme is explicitly dealing with the representation.

Class 2 (Teacher-sequence): Let us note that this facet is not introduced in session I where the teacher introduces direct relationships between force exerted on a moving object and the change in its motion (direction, velocity) to show "the effect of force". This facet is introduced during the second session, theme 1 in connection with the recall of the principle of reciprocal actions when interpreting a situation where the teacher pushes a student to show the effect of the force. In the next theme, the teacher introduces several new elements of knowledge related to the vector representation of force. During session III theme 3, this facet is used in a situation where the aim was to establish a list of forces exerted on an object and the relationships between the sum of forces and variation of velocity. The teacher clearly states that the sum of forces does not necessarily have the direction of the motion: "So it's not because it moves up that the forces acting on the whole object to give a resultant upwards force, it can move upwards very well while the forces exerted on the object have a resultant downwards force ... "

At this stage of our analysis, it appears that the results at microscopic and mesoscopic scales can be easily related and allow us to situate the elements of knowledge *and to reconstruct their meaning in the classroom situation*. In class 1, not only the facets directly relevant to answer the questions are more often used in a meaningful way, but also the corresponding elements of knowledge are involved in different representations (diagram, vector and nature language) and often related with a clear distinction between action-force and motion, action and force being strongly related; moreover these elements are used in more various situations than in class 2 (Malkoun, submitted).

Case of notions or concepts and their formulation

Contrary to the previous questions, these questions on weight and force exerted on the Earth involve more limited set of elements of knowledge; they are delimited to the case of the Earth.

A first link between the questionnaire and the classroom practice: the facets

Several facets can be involved in the questions where the weight or the force exerted by the Earth are involved. Let us note that we did not anticipate the students' difficulty of not recognizing the identity of these two wordings, then we did not differentiate "the force exerted by the Earth on an object" and "the weight of an object" in the facets. Table 7 gives the facets involving the weight or the force exerted by the Earth.

Facets	**Class1** Wh C	**Class 2** Wh C
Earth always acts on (attracts) objects'	15	2
The action of the Earth on the objects is a distant action	6	3
The action of the Earth is downwards vertical always	5	0
The gravity (or the weight) is the result of the action of the Earth	0	0
The objects fall down because of the Earth	1	0
Earth always exerts a force on other objects	2	14
The force exerted by the Earth on an object is the weight of the object	1	8
The force exerted by the Earth on an object is a vertical vector always oriented downwards	4	7
The force (the action) exerted by the Earth and the force (the action) exerted by the ground are not the same forces	4	1
TOTAL	**38**	**35**

Table 7: Number of facets related to Earth involved in classes 1 and 2 when the class organisation is in whole class

Again, a clear difference deals with the facet "The force exerted by the Earth on an object is the weight of the object" which explicitly establishes the equivalence between the force exerted by the Earth and the weight (8 times in class 2 against 1 in class 1). To supplement this analysis, we counted the number of times the word "weight" was used in the transcriptions. Even if the transcriptions are not finely done, the results give an idea since the number of times is 10 for class 1 and 97 for class 2. These results show the similar total number of facets in the two classes and, in the same time, the difference in the wordings in terms of weight or in force exerted by the Earth (table 7). This difference can account for the meaning constructed by the students.

Meanings involved in classroom practice at the place where facets are

In class 1, the use of the concept of force is mainly associated to a single wording whatever the force even for weight, reaction etc., and its notation associated to the vector representation is always $F_{x/y}$. In class 2, like for example in Session III theme 3, the representation of forces exerted on an object (in this case a ping-pong ball maintained in water) is named P. This leads the teacher to make explicit that the force exerted by the Earth is the weight. And this type of situation appears in sessions 3, 4, 5, 6. Comparing the uses of vector representation for the two classes, the analyses in terms of facets and themes show clearly differences between the two classes. The meso analysis in terms of topogenesis and more generally in terms of didactic contract, shows that in class 1 teacher always asks the students to draw the representation correctly ($F_{x/y}$) when the students draw their solution on the blackboard and when she discusses with small groups; it is a constant requirement throughout the teaching sequence and the teacher emphasizes this aspect much more than the class 2 teacher.

These analyses show that facets are good landmarks to analyse the meanings of the classroom discourse when *specific elements of knowledge* are involved. They allow situating the moments of the teaching sequence to analyse the classroom life at the meso level in terms of chrono, topogenesis, and didactic contract; this meso analysis is crucial to understand the relations between students' performances and classroom practices.

Conclusion

Comparing the approaches presented in the introduction with our approach could seem premature to the extent that the first ones are carried out at large scale on representative samples whereas ours uses a case study methodology. However, we think that this approach can be developed to allow the researchers to adapt it to large-scale analyses. As shown figure 10, there are several main differences in these two types of approaches.

In the first case, classroom is viewed as opportunities to learn, *its modelling is driven by learning hypotheses*, and *its model consists of categories* related to observable facts or events or more deeper components of classroom (figure 10, case 1). In the second case, classroom is viewed as a place where the teacher with his/her students constructs *meaning of the taught knowledge in order that students learn it. Thus classroom is considered as a system characterized by the dynamics construction of the taught knowledge within communicative processes*. The concepts of chrono, topo, meso genesis and didactic contract orient the way of "seeing" the classroom (figure 10, case 2).

Moreover, in case 1, the relationships between test-questionnaires and classroom practice are general in the sense that the learning classroom environments, if they respect the good variables, should predict students learning of a rather large variety of knowledge in a given discipline (or a group of disciplines like science). In case 2, the relationships between classroom practices and test performances are established on the basis of same specific small elements of knowledge, and on the meaning made at the larger scale of a theme and during the whole sequence.

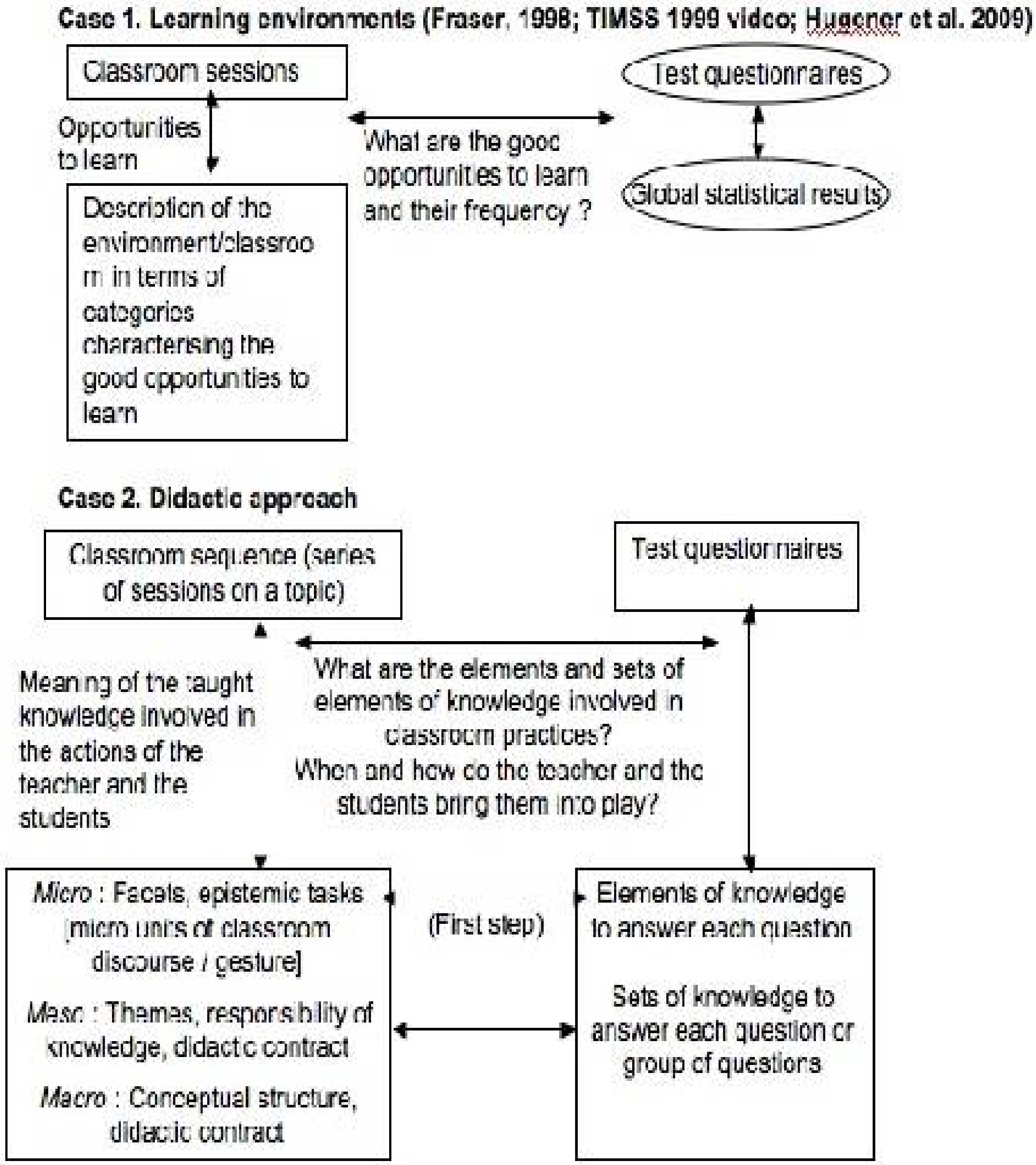


Figure 10: Two different approaches to relate classroom practices and students' performances

In case 2, the way of viewing the class modifies the question of good practices. Good practices are not really associated to specific teaching situations but to a *dynamics of the development of teaching processes associated to contents* during a rather long period of time (several weeks or months). The question is no more focused on characterizing a "state" of the classroom during a session, but on the *evolution* of the classroom over time from the perspective of the meaning construction in the classroom of the taught topic.

References

Brousseau, G. (1998). *Théorie des situations didactiques*. Grenoble: La pensée sauvage.
Brückmann, M., Duit, R., Tesch, M., Fischer, H., Kauertz, B., & Labudde, P. (2007).

The potential of video studies in research on teaching and learning science. In R. Pintó & D. Couso (Eds.), *ESERA Selected Contributions book.* (pp. 77-89). Berlin: Springer.
Bruner, J. S. (1996). *The culture of education*. Cambridge, Massachusetts: Harvard University Press.
Chevallard, Y. (1991). *La transposition didactique* (2ème Ed.). Grenoble: La Pensée Sauvage.
Chevallard, Y. (1999). L'analyse des pratiques enseignantes en théorie anthropologique du didactique. *Recherches en didactique des mathématiques, 19*(2), 221-266.
Coulaud, M. (2005). *Evaluer la compréhension des concepts de mécanique chez des élèves de secondes : développement d'outils pour les enseignants.* Thèse de doctorat, Université Lyon 2, Lyon.
Cross, D., Khanfour-Armalé, R., Badreddine, Z., Malkoun, L., & Seck, M. (2009). Méthodologie de mise au point d'un consensus entre chercheurs: le cas du thème, *1er colloque international de l'ARCD Où va la didactique comparée*. Université de Genève.
Dessus, P. (2007). Systèmes d'observation de classes et prise en compte de la complexité des événements scolaires. *Carrefours de l'éducation, 23*, 103-117.
Fischer, H., Duit, R., & Labudde, P. (2005). Video-studies on the Practice of Lower Secondary Physics Instruction in Germany and Switzerland – Design, Theoretical Frameworks, and a Summary of Major Findings. In R. Pintò & D. Couso (Eds.), *Proceedings of the fifth international ESERA conference on contributions of research to enhancing students' interest in learning science* (pp. 830-834). Barcelona, Spain.
Flanders, N. A. (1976). Analyse de l'interaction et formation. In A. Morrison & D. McIntyre (Eds.), *Psychologie sociale de l'enseignement* (Vol. 1, pp. 57-69). Paris: Dunod.
Ford, M. J., & Forman, E. A. (2006). Redefining Disciplinary Learning in Classroom Contexts. *Review of Research in Education, 30*(1), 1-32.
Fraser, B. J. (1998). Science learning environments: assessment, effects and determinants. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 527-564). Dordrecht: Kluwer Academic Publishers.
Galili, I., & Hazan, A. (2000). The influence of an historically oriented course on students' content knowledge in optics evaluated by means of facets-schemes analysis. *American Journal of Physics, 68 (Supplement)*(7), S3-S15.
Givry, D. (2003). *Étude de l'évolution des idées des élèves de seconde durant une séquence d'enseignement sur les gaz.* Thèse, Université Lumière Lyon 2, Lyon.
Givry, D., & Roth, W.-M. (2006). Toward a new conception of conceptions: Interplay of talk, gestures, and structures in the setting. *Journal of Research in Science Teaching, 43*(10), 1086-1109.
Hiebert, J., Gallimore, J. H. R., Garnier, H., Bogard, K., Hollingsworth, G. H., Jacobs, J., Chui, A. M.-Y., Wearne, D., Smith, M., Kersting, N., Manaster, A., Tseng, E., Etterbeek, W., Manaster, C., Gonzales, P., & Stigler, J. (2003). *Teaching Mathematics in Seven Countries. Results from the TIMSS 1999 Video Study*: National Center for Education Statistics (NCES) U.S. Department of Education.
Hugener, I., Pauli, C., Reusser, K., Lipowsky, F., Rakoczy, K., & Klieme, E. (2009). Teaching patterns and learning quality in Swiss and Germa mathematics lessons. *Learning and Instruction, 19*(1), 66-78.
Küçüközer, A. (2000). *Une compréhension de la notion d'interaction dans le cadre*

d'un enseignement de mécanique. Mémoire du DEA Didactiques et Interactions, Université Lumière - Lyon 2.

Küçüközer, A. (2005). *L'étude de l'évolution de la compréhension conceptuelle des élèves avec un enseignement. Cas de la mécanique en 1ère S.* Thèse, Université Lumière Lyon 2, Lyon.

Lemke, J. L. (2001). The long and the short of it: comments on multiple timescale studies of human activities. *The Journal of the Learning Sciences, 10*(1&2), 17-26.

Ligozat, F. (2008). *Un point de vue de didactique comparée sur la classe de mathématiques.* doctorat, Université de Genève et université de Provence.

Malkoun, L (submitted). Continuity of knowledge: an aspect of classroom practices to interpret students' performance.

Malkoun, L. (2007). *De la caractérisation des pratiques de classes de physique à leur relation aux performances des élèves: étude de cas en France et au Liban.* Doctorat, Université Lyon 2 / Université libanaise, Lyon/Beyrouth.

Marlot, C. (2008). *Caractérisation des transactions didactiques : Deux études de cas en découverte du monde vivant au cycle II de l'école élémentaire.* Doctorat en sciences de l'éducation, Université Rennes 2, Rennes.

Mercier, A., Schauber-Leoni, M. L., & Sensevy, G. (2002). Vers une didactique comparée. *Revue Française de Pédagogie, 141*, 5-16.

Minstrell, J. (1992). Facets of students' knowledge and relevant instruction. In R. Duit & F. Goldberg & H. Niedderer (Eds.), *Research in physics learning: Theoretical issues and empirical studies* (pp. 110-128). Kiel: IPN.

Mortimer, E. F., Massicame, T., Tiberghien, A., Buty, C. (2007). Uma metodologia para caracterizar os gêneros de discurso como tipos de estratégias enunciativas nas aulas de ciências, *A pesquisa em ensino deciências no Brasil: alguns recortes* (Vol. 1, pp. 53-94): São Paulo : Escrituras.

Ohlsson, S. (1996). Learning to do and learning to understand: A lesson and a challenge for cognitive modeling. In P. Reiman & H. Spada (Eds.), *Learning in Humans and Machine* (pp. 37 - 62). Oxford: Pergamon Elsevier Science.

Psillos, D., & Kariotoglou, P. (1999). Teaching fluids: Intended knowledge and students? Actual conceptual evolution. *International Journal of Science Education, 21*(1), 17-38.

Roth, K. J., Druker, S. L., Garnier, H. E., Lemmens, M., Chen, C., Kawanaka, T., Rasmussen, D., Trubacova, S., Warvi, D., Okamoto, Y., Gonzales, P., Stigler, J., & Gallimore, R. (2006). *Teaching Science in Five Countries: Results From the TIMSS 1999 Video Study Statistical Analysis Report* (NCES 2006-011). Washington: U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

Seidel, T., & Prenzel, M. (2006). Stability of teaching patterns in physics instruction: findings from a video study. *Learning and Instruction*, 228-240.

Sensevy, G. (2007). Des catégories pour décrire et comprendre l'action didactique. In G. Sensevy & A. Mercier (Eds.), *Agir ensemble : Eléments de théorisation de l'action conjointe du professeur et des élèves* (pp. 13-49). Rennes: Presses Universitaires de Rennes (PUR).

Sensevy, G., Tiberghien, A., Santini, J., Laube, S., & Griggs, P. (2008). An epistemological approach to modeling: Cases studies and implications for science teaching. *Science Education, 92*(3), 424-446.

SESAMES. (2007-2010). Available on *PEGASE* web site. INRP.: pegase.inrp.fr [Retrieved, March 2010].

Tiberghien, A., & Malkoun, L. (2007). Différenciation des pratiques d'enseignement et acquisitions des élèves du point de vue du savoir. *Education et Didactique, 1*, 29-54.

Tiberghien, A., & Malkoun, L. (2009). The construction of physics knowledge in a classroom community from different perspectives. In B. Schwarz, T. Dreyfus & R. Hershkovitz (Eds.), *Transformation of knowledge through classroom interaction* (pp. 42-55). New York: Routledge.

Tiberghien, A., Malkoun, L., & Seck, M. (2008). Analyse des pratiques de classes de physique : aspects théoriques et méthodologiques. *Les dossiers des sciences de l'éducation, 19*, 61-79.

Tiberghien, A., Vince, J., & Gaidioz, P. (2009). Design-based Research: Case of a teaching sequence on mechanics. *International Journal of Science Education, 31*(17), 2275 - 2314.

Viennot, L. (2001). *Reasoning in physics: the part of the common sense*. Dordrecht, NL: Kluwer.

Vygotski, L. S. (1934/1997). *Pensée et langage* (3ème ed.). Paris: La Dispute.

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