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Modeling the Individual Within the Group: an Interdisciplinary Approach to Collaborative Knowledge Construction

APPENDICES

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Learning physics as *coherently packaging* multiple sets of signs

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Abstract: This paper studies the multimodal reformulations that teachers and students make when they talk about and do physics experiments in class. Using the framework of semiotic bundles, we show that reformulating aspects having to do with physics knowledge while moving between talk, gestures, drawings and manipulations is done differently by experts and novices. Analysis of video excerpts illustrate that teachers are able to coherently package multiple sets of signs throughout their discourse and actions in the classroom, but students who are learning physics have specific problems that this framework makes evident. In particular, successfully reformulating from one semiotic resource to another implies that the first resource be correctly constructed. In addition, specific *tool affordances* hinder students in their attempt to coherently package multiple sets of signs while this is not the case for teachers. We conclude by suggesting ways in which teachers can ease students' difficulties in constructing semiotic bundles.

Introduction

Our research team has many years of experience in designing teaching sequences for upper secondary school in physics and chemistry (e.g. Buty, et al., 2004). These groups are based on the collaboration of practicing teachers and researchers. One of the main hypotheses stemming from research on the design of teaching sequences is that the modeling activities of students in relation to an epistemological point of view concerning physics' functioning must be taken into account (Bécu-Robinault, 2002). In addition, other theoretical underpinnings are taken into account, such as the role of social interactions in learning (e.g. Doisy & Mugny, 1984) and research results concerning misconceptions (cf. Duit & Von Rhöneck, 1998 for a meta-review). Since 1997, we have developed a range of teaching-learning sequences, concerning learners aged from 15 to 18 all of which have been implemented in classrooms and evaluated from teaching and learning perspectives. Our results show that teachers are able to use the teaching-learning sequences and associated documents and they also perceive improvements in student learning. Despite this, evaluations also show that, unexpectedly, a variety of teachers devote a great deal of time to the reformulation of the ideas in the elaborated documents (Lund & Bécu-Robinault, forthcoming). We know teachers have a fixed duration to teach their class and do not purposefully waste time, so we hypothesize that this phase is important for helping students grasp the knowledge to be taught. In this study we explore the implicit reasons for which teachers may perform such a reformulation activity and this prompts us to look more closely at the initial lessons of a particular physics teaching-learning sequence.

In what follows we will present our theoretical framework, describe our empirical study, present our analyses and results and conclude with perspectives for further work.

Theoretical framework

It is well known that physics learning is a complex activity. In this paper, we choose to address students' conceptual difficulties in the particular case of learning electricity through the study of multimodal reformulation as a tool to co-construct discourse (De Gaulmyn, 1987; Apotheloz, 2001; Lund, 2007). We will use the notion of semiotic bundles as a method for explaining students' difficulties (Arzarello, 2004). In the sections that follow, we present

these notions and set the scene for showing how reformulating aspects of one particular semiotic resource into another one is an expert activity for teachers but fraught with difficulties for students.

Multimodal reformulation

The term multimodal is often used to signify the medium in which a particular message can be expressed, for example text or graphics (e.g. Pineda & Garza, 2000). The authors Kress & Van Leeuwen, (2001) distinguish between modes and media: modes are the abstract, non-material resources of meaning-making whereas media are the specific material forms in which modes are carried out. The mode of gesture is carried out in the media of movements of the body. Different media afford different kinds of meaning (Dicks, et al. 2006), e.g. expressing an idea in writing or speech affects what is conveyed. Here, we use the term multimodal to describe the addition of non-verbal human face-to-face interactive phenomena such as gesture, gaze, posture, object manipulations, etc. to speech, studied extensively as a phenomenon in its own right by researchers such as Kendon (2004), Cosnier, (2000), McNeal (1992) and Brassac, et al. (2008).

Many interactive situations whose objective is learning presumes a dissymmetry between interlocutors in terms of their knowledge. This dissymmetry calls for adjusting discourse so that interlocutors reach mutual comprehension and common ground. Teachers' discourse does not escape from these adjustments and they often occur as reformulations, meaning that what learners say is put by the teacher into more conventional words (Chouinard & Clark, 2003). In this study, we borrow a different focus for the definition of reformulation from Apotheloz (2001), elaborated in the context of collaborative writing. This is an orographic situation that articulates two different modes, speaking and writing. For Apotheloz, cooperation during such a task consists in "continuously exhibiting, that is at each step, the manner in which what is formulated articulates with what has already been formulated" (p. 62, our translation from French). We study this same phenomenon of reformulation, but in a situation where there is a plurality of multimodal activity: teachers and students speak, write, gesture, draw and manipulate objects and we see that the reformulations between modes that are carried out by teachers and those that are carried out by students differ greatly in how such a reformulation provides for the construction of meaning.

Semiotic Bundles

We use Arzarello's (2004) semiotic bundle to interpret such multimodal reformulation, originally defined to analyze interactions around mathematics learning. A semiotic bundle is a collection of semiotic sets and a set of relationships between the sets of the bundle. A semiotic set is composed of three elements. The first component is a set of signs that may *be produced* with different intentional actions (speaking, writing, drawing, gesturing, handling an artifact). The second component is a set of modes *for producing* the signs and possibly transforming them. The modes can be rules or algorithms, but can also be more flexible action or productions modes, such as the modes referred to in the previous section, comparable to the intentional actions of Arzarello (speaking, writing, drawing, gesturing, handling an artifact). The third and final component is a set of relationships among the produced signs and their meanings embodied in an underlying meaning structure. A semiotic bundle is a dynamic structure changing over time due to the semiotic activities of the participants who are constructing it.

Empirical study

This study has been carried out in the context of a research-action group that designs teaching sequences for physics (Bécu-Robinault, 2007; Buty et al, 2004). All the teaching sequences have been co-elaborated by researchers and practicing teachers, implemented in classrooms

and evaluated from teaching and learning perspectives. In this presentation, we focus on the electro kinetics sequence, lasting 3 months, for grade 7 in the French school system. The teaching and learning of electricity has been the object of many investigations in science education. From international research results, we know that students encounter deep-level conceptual and reasoning difficulties in understanding introductory electricity. The main difficulty concerns notions of current, electric current and energy that are not differentiated by students (Psillos et al., 1988). Many teachers spontaneously use analogies, such as a water analogy, to teach electricity. Indeed, using analogies in teaching is thought to provide learners with tools that facilitate science understanding and promote conceptual change. We thus chose to introduce an analogy, in order to predict and interpret phenomena without using any formal concepts and to help students to develop an understanding of electricity and energy concepts (cf. Scott et al., 2006). This analogy relates these concepts to familiar every day objects (loaves of bread represent energy, delivery vans in motion represent the current, the bakery and the supermarket are respectively the analogues of the battery and the light bulb).

Short description of the lessons studied

In the French curriculum, electricity at grade 7 is taught through a phenomenological study of electrical circuits. In this presentation, we will focus on the first two lessons dedicated to the study of the simple circuit (how to light a bulb with a battery) and to the introduction of an analogy used for teaching (differentiation of current and energy, although we will not focus on energy in our examples). The first lesson is a necessary preliminary, in order that students understand how to handle electrical devices, identify the different terminals, and have no choice but to build a loop with the battery, wires and bulb. To understand how a simple circuit functions, students are asked to draw their experiment before handling electrical devices. This lesson begins with the presentation of a well-known object, a MagliteTM flashlight. Students usually question a battery's freshness and this cannot be interpreted in terms of current so the second lesson addresses this concern. With the help of the analogy, we suggest that the current implies thinking with a circuit perspective and that energy implies thinking with a chain perspective. Students are thus asked to connect each term of the analogy and its corresponding physical object in the world and use a variety of semiotic resources (modes producing signs).

Methodology

Video recordings and partial multimodal transcriptions of one pair of students and a teacher involved in the research-action group were made and written documents distributed by the teacher were collected. The transcriptions were done according to the following conventions (cf. [Table 1](#)).

Table 1. Conventions for multimodal transcriptions

Multimodal transcription conventions
^ : rising tone
‘ : falling tone
[: overlapping speech
<u>a</u> : underlining words implies insistence
: ou ::: : a sound is drawn out
= : immediate chaining with next utterance

(.) : micropause
(3 s) : pause in seconds
(...) : a cut in the recording
(inaudible) : inaudible passage
** gestures are described and shown in relation to the discourse that was spoken when they were performed

Verbal and non-verbal behavior of the teacher and students were analyzed in relation to the classroom production. Written teaching-learning materials were used to define what type of resources students had at their disposal to build semiotic sets and bundles.

Analyses and results

We present three short video extracts and their corresponding analyses. Before the third extract, we describe three groups of students' drawings. The first extract corresponds to the presentation of the analogy: the teacher defines each term and correspondence. In the second, the teacher constructs an experiment (lighting the bulb by connecting two wires to a battery) that corresponds to a physical object, a drawing of that object and a drawing of the experiment. In the third, the students attempt this same experiment.

A teacher's complex yet coherent semiotic bundle

The first extract is from the second lesson and concerns an integration of two semiotic sets into a coherent semiotic bundle. The first semiotic set contains the model of the electrical circuit (Figure 1, left) and the second contains the analogy of the electrical circuit, built around a bakery that delivers bread to supermarkets (Figure 1, right).

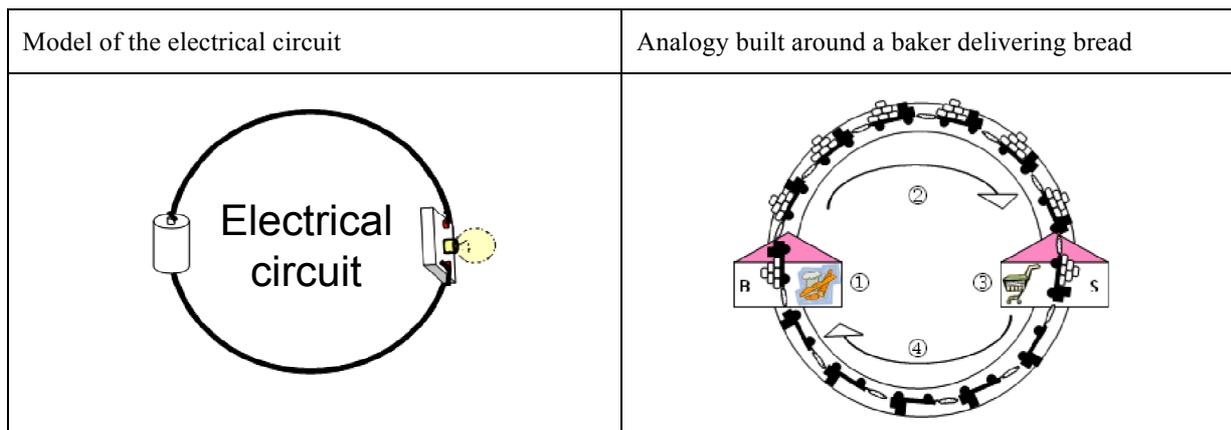


Figure 1. Two semiotic sets: the electrical circuit and the bakery analogy.

The elements of the analogy are presented below; each numbered element corresponds to the circled number on the figure at the right.

1. Each bakery always loads the same number of loaves of bread at into each delivery truck.
2. All delivery trucks move at the same speed. The speed of the delivery trucks is adapted to the demand of each supermarket.

3. The delivery trucks arrive at the supermarket where the loaves of bread are delivered, transformed and then sold to clients. All of the delivery trucks delivery all of their loaves of bread.
4. After delivery, each truck returns empty to the bakery in order to get a new load of loaves of bread.

The relations allowing the coherence of the semiotic bundle are provided by teacher's talk and gestures concerning each semiotic set and by written documents distributed at the beginning of the lesson (cf. Table 2 where T stands for teacher and S for student).

Table 2. Teacher discourse and gestures during her presentation of the bakery analogy.

Time	Discourse	Gestures
7'33	T: the electric current can can circulate Ok and this electric current what is it in the delivery truck analogy^	traces a circle with her hand, then traces another rapidly traces a smaller circle with her hand raises her right hand in order to indicate the change from the domain of electricity to the analogy
	S: the delivery [trucks	
	T: [why yes ^	points her finger at a student
	S: the lineup of delivery trucks=	
7'43	T: =the lineup of delivery trucks very good it's the lineup of delivery trucks uhh it's the fact that it's the circulation of the delivery trucks the trucks are moving so the electric current circulates	traces a circle with her hand traces a circle with her hand, then traces another circle traces a circle with her hand traces a half circle, pauses at the bottom finishes her circle traces a half circle with her hand, pauses between the bottom and the top, finishes her circle traces a circle pauses between the bottom and the top traces a circle that is almost complete with her hand
7'52	ok it's all of the trucks that circulate very good	

Our videotape shows that gestures are identical when the reference domain changes (from electrical circuit to bakery analogy). The teacher makes a circular gesture to mimic both circulation of electricity (first semiotic set) and traffic of delivery trucks (second semiotic set). This circular gesture is repeated eleven times (cf.

Figure 2), in association with the verbalization “circulation of delivery trucks” or “circulation of current”. The rhythmic gesturing emphasizes the continuous aspect of the electrical circuit (delivery trucks) and allows the teacher to insist upon the systemic point of view. Moreover, she makes pauses corresponding to the positions of the supermarket (bulb) and of the bakery (battery). We argue that these similar gestures within two separate semiotic sets help students to integrate the analogues in a single and coherent semiotic bundle.



Figure 2. Teacher gesturing in order to make the link between circulation of delivery trucks and circulation of current.

However, problems begin for students at a much earlier stage. The goal of this paper is to show that building complex semiotic bundles such as this one can be difficult for students unless each semiotic set they add to their bundle under construction (indeed each semiotic resource that they add to their set) is done in a coherent way. In order to illustrate this, we look at the bundle at an earlier stage, before the analogy has been introduced, when the objective is to build a simple circuit. In this context, a first semiotic set will consist of a drawing, written comments on that drawing, gestures about that drawing and a verbal description of that drawing, all done by the students. A second semiotic set will consist of handling the experimental apparatus, talking about handling it, performing gestures to show objects, all mostly done by the students alone. Having said that, semiotic sets and bundles can be co-constructed between teachers and students, adding to the complexity of our analytical viewpoint.

A teacher’s initial coherent semiotic bundle

Figure 3 shows an example of how an expert teacher is able to construct a coherent semiotic bundle from a variety of physical objects and functional representations of those objects (following her own instructions given to the students during the first lesson, as stated below):

1. Do a drawing that represents what happens inside the flashlight when it is turned on and is shining (a photo of this object is given – it’s a familiar object for all students).
2. Draw diverse experiments with the proposed objects that will permit you to verify what happens inside the flashlight when it is shining.
3. After the teacher gives permission, ask for the necessary objects and perform the experiments.
4. Is your drawing for question 1 correct? If it isn’t, do another one that shows what is happening inside the flashlight when it is shining.

Figure 3 shows that it is easy to link each part of the drawings with the experimental apparatus, because aspects and locations of objects (battery, bulb) are similar. These relations are also facilitated because drawing and experimental apparatus are built on the basis of the electrical diagram the teacher has in mind (far right of Figure 3). The teacher is thus able to move from one mode to another while maintaining coherency and building meaning. We also notice that the teacher does *not* draw the clamps of the crocodile clips in her drawing of the experiment, as they are not relevant to carrying out the experiment. As an expert, she is able to model the physical objects in a way that is pertinent for the experiment she will be carrying out, only paying attention to the characteristics that are relevant for that objective.

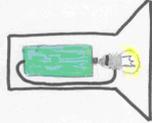
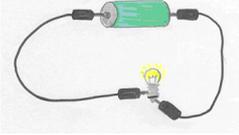
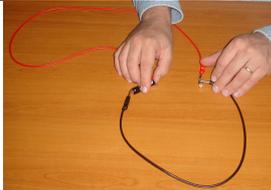
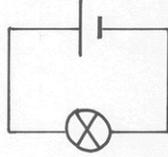
The object studied	The functional drawing	The drawing of an experiment explaining functional aspects	The experiment carried out	Diagram that models the function
				

Figure 3. An *a priori* didactical analysis of multimodal and polysemiotic coherence for the simple circuit

Students’ difficulties in constructing the initial semiotic bundle

We first show an analysis of three different student groups’ drawings in order to illustrate the range of difficulties students have when they propose experiments that fit to their representation of what happens inside the flashlight when it is turned on and is shining (cf. Figure 4). One of the first difficulties students experience while building the semiotic bundle is connecting the experimental apparatus to the initial ‘thought objects’ that represent the flashlight parts in their drawing. From an expert point of view, the real object (the flashlight), the drawings and the experimental apparatus as well as discourse and gestures about these, form one semiotic set. On the other hand, we see that students already have difficulty relating these elements to each other, *within the semiotic set itself*, so adding another set to this one (e.g. the bakery analogy) to make a semiotic bundle seems, at this stage, to be out of these students’ reach.

Group#	The functional drawing	The drawing of an experiment explaining functional aspects	Comments

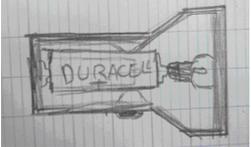
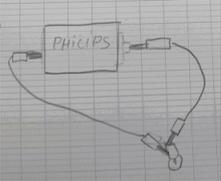
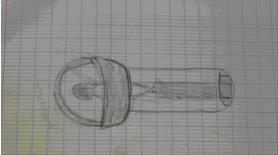
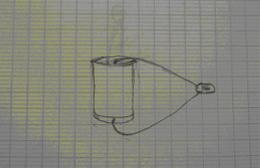
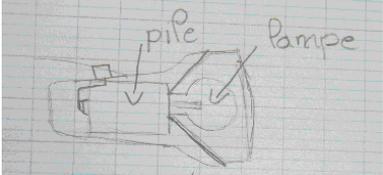
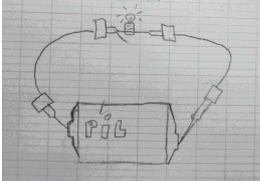
1			<p>There is no wire in the functional drawing. Names of batteries are different from one drawing to another although the battery is the same. However, the drawing of the experiment is correct.</p>
2			<p>Students use one wire to connect either the battery to the bulb or the battery to itself. They tell their teacher that there is a button they can press to initiate battery functioning.</p>
3			<p>The functional drawing reproduces the general look of the bulb.</p> <p>The drawing of the experiment takes into account the objects students have to use and the physical affordances of their experimental apparatus are evident in their drawing, even though this is not pertinent.</p>

Figure 4. Example of students' polysemiotic incoherencies for the simple circuit.

The second extract (cf. Figure 5) concerns two students (Pierre and Jacques) who experience many difficulties in attempting to perform the simple circuit experiment as described above. Firstly, the students' drawing of the experiment is not correct. In order for the bulb to light up, one wire must be touching the very end of the bulb and the other wire must be touching the middle part (cf. the teacher's drawing in Figure 3).

So in this case, Pierre and Jacques are attempting to create coherency within an underlying meaning structure between two modes while trying to respect a drawing that will not help them. Secondly, the physical affordances of the crocodile clips (not shown in their drawing, but visible in the photo), entice the students to clamp them onto something, but the bulb does not allow clamping. Instead, one must just maintain the clamps stable (without trying to open them) so that they are touching the correct parts of the bulb and battery (cf. the teacher's experiment, above). Contrary to instructions, Pierre and Jacques do not redraw the experiment in an attempt to focus on how the electrical connections must be made, although this could have helped them.

The object studied	The drawing of an experiment explaining functional aspects	The experiment carried out a first time
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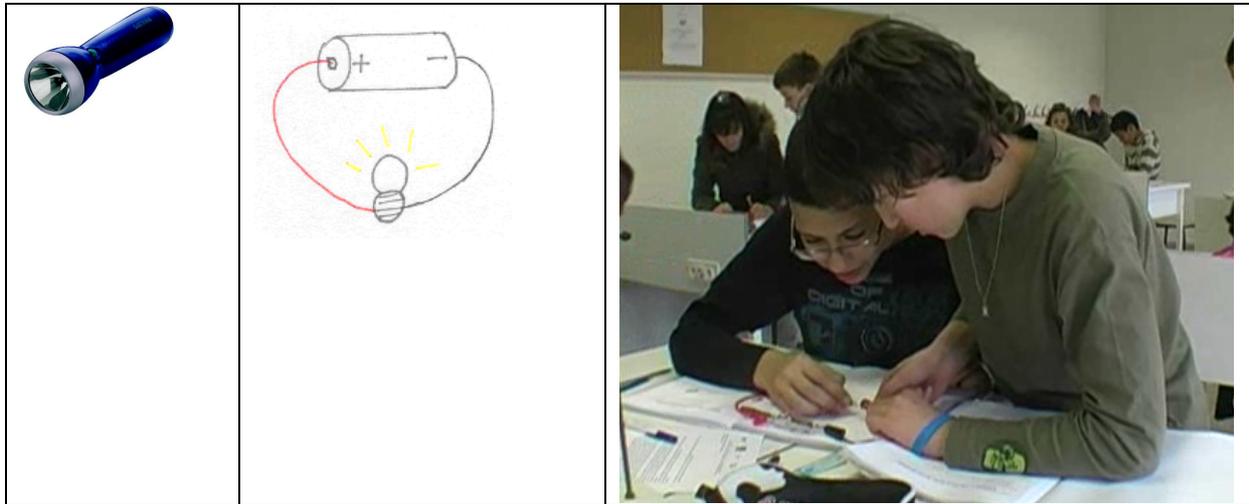


Figure 5. Analysis of two students' multimodal and polysemiotic *incoherence* for the simple circuit.

Later on, another student shows Pierre and Jacques how to light the bulb with one wire. On this basis, they make several trials and suddenly, it works. Pierre says “it’s magic!”, but since he hadn’t drawn any new representation of the experiment, this event remains at the level of the magic trick for him, because it is not integrated into the semiotic bundle. This interpretation is also illustrated by a final trial made with the teacher that does not work either. Figure 6 and Table 3 with the associated discourse of the teacher shows that Pierre has not yet understood how to hook the wires up to the battery. In fact, Pierre and Jacques followed their drawing, but this did not result in a lighted bulb and so they were stuck.

Table 3. Teacher discourse when a student helps him to hold the experiment.

Time	Discourse	Gestures
32'44	T: no, not really here well we'll see that later on but it should not be placed on the same area of the bulb, it should be on this area and on the contact	points to the wire on the bulb points to the lower side of the bulb and the bottom of the bulb



Figure 6. Pierre is called upon to help the teacher hold the experiment.

Conclusions and further work

In this article, we have used the notions of multimodal reformulation and the semiotic bundle to describe the ways in which meaning-making occurs when students and teachers speak, gesture, draw and manipulate experimental apparatus. Choosing to look at meaning-making through the construction of such semiotic bundles allows us to meet two goals. Firstly, we render explicit the expertise of teachers (i.e. their ability to seamlessly change modes, to select the appropriate characteristics of experimental apparatus to model in relation to a known objective and finally to coherently construct a complex semiotic bundle). Secondly we pinpoint where difficulties appear for students. In particular, if students erroneously construct a particular semiotic resource (e.g. the drawing for the experiment), they won't be able to build an underlying structure of meaning between it and the next semiotic resource they reformulate into (e.g. experimental apparatus). Secondly, the physical affordances of experimental materials (e.g. the crocodile clips) can hinder reformulation between a semiotic resource in one set and a semiotic resource in another (e.g. between drawing and experimental manipulation). We can conclude that it is useful to consider teaching sequences from the viewpoint of the *complexity* of the semiotic bundle that is being built. Each new semiotic resource and set that is added to the bundle must be constructed without error so that when students attempt to reformulate a given resource into another mode, they are able to do so. Physical objects to be manipulated must be carefully chosen so as to not mislead students by material affordances that are not relevant to the task at hand. In sum, each step of the construction of each semiotic set that makes up a semiotic bundle can be seen as a checkpoint for student understanding.

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Conceptual Change and Sustainable Coherency of Concepts across Modes of Interaction

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Abstract (for e-Book ONLY!)

Our analyses illustrate nine instances of what we call multimodal and multimedial reformulations of content beginning either with drawings of physics experiments and going to the manipulation of the physics experiments themselves or beginning with the experiments and going to the drawings. We postulated that each time one of these reformulations occurred, it was a potential (yet rare) pivotal moment for conceptual change because content was being transformed across modes and media. Within the nine instances of reformulation, we found two types of pivotal moments (three instances in all). The first type was changing one's conception from an intuitive everyday view on physics to a canonical view of physics. The second was maintaining a canonical view of physics, but while also integrating more complexity in terms of experiments constructed, drawings made or concepts talked about. In addition, the notion of the semantic bundle enabled us to show how the ongoing interaction supplied building blocks that illustrated either sustained conceptual change coherent with canonical physics or difficulties that students faced.

Conceptual Change and Sustainable Coherency of Concepts Across Modes of Interaction

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Introduction

Physics teachers habitually organize teaching sequences in order to favor students' co-construction of physics concepts across different ways of communicating and interacting. Such an organization is meant to provoke conceptual change. In this chapter, we present two types of conceptual change. The first is changing one's conception from an intuitive everyday view on physics to a canonical view of physics. The second is maintaining a canonical view of physics (hence, the sustainability in our title), but while also integrating more complexity — either more objects from the experimental field into one's understanding (e.g. adding a second bulb to a simple battery-bulb circuit), by appropriating a new external representation (e.g. a new Group Scribbles drawing of a more complex circuit), or by integrating into one's talk references to new objects, new external representations, or new concepts.

In this chapter we will address students' conceptual difficulties in learning electricity, through the study of multimodal and multimedial reformulation as a tool to co-construct discourse (De Gaulmyn, 1987; Apotheloz, 2001; Lund, 2007), thus taking into account all the semiotic resources that co-participants do when they work together to solve physics problems. We first present our theoretical framework and methodology through a discussion of five specific dimensions (cf. Lund & Suthers, Chapter 2, this volume), our results and finally, our conclusions.

Dimensions of our analysis

Below, each dimension is defined according to our analyses on that dataset with the view of facilitating comparisons with other analysts.

Theoretical assumptions

We use five theoretical positions and/or constructs, construed as a series of steps. Each step is relevant for our approach to understanding difficulties students have in co-constructing and sustaining coherency of physics concepts across modes of communication. We begin with a view on describing physics learning as acquiring the competence to connect theories and models with objects and events in an experimental field (Bécu-Robinault, 2007). These modeling activities allow the prediction or interpretation of phenomena on the basis of theories. These theories can be intuitive and based on everyday experience or canonical or some combination of both. In this case study, we assume that students have manipulated flashlights during their everyday experience, and that this has led them to build intuitive knowledge about ways to light a bulb with batteries. This intuitive knowledge, essentially based on causal relations, is not necessarily compatible with canonical knowledge concerning electricity flow and the ways to connect electric dipoles. We note that conceptual change — some of which is the transfer of knowledge from one situation to another (Schwartz, Varma & Martin, 2008) — involves progressively changing how knowledge is organized through the use of talk and both internal and external representations (Ainsworth, 2006). Concerning the former, knowledge is organized in domain specific theory-like structures that students can change by both bottom-up and top-down learning mechanisms. Neither the situative nor the cognitive perspective on learning can alone account for knowledge transfer and so we propose

— along with Vosniadou (2007) — that Hutchin’s distributed cognition (1995) be adopted as it allows for describing change in both internal representations (some form of knowledge represented in human memory) and in the knowledge represented in external representations. Our second step concerns the theoretical assumptions underlying multimodal discourse analysis; which elements are involved in the learners’ communication and interaction? We note that language is a form of action and interpreted as a system of meanings, accompanied by forms through which meanings can be realized (Halliday, 1994), rather than statements corresponding to phenomena with an independent existence. We choose to study what we call the ⟨mode, medium⟩ couplet where modes are the abstract, non-material resources of meaning-making and media are the specific material forms in which modes are carried out Kress & Van Leeuwen (2001). For example, each mode of communication in this corpus is coupled with a particular medium that allows for its expression: ⟨talk/speech⟩, ⟨drawing/GS⟩, and ⟨manipulation/battery-bulb-wires⟩. Such couplets allow us to distinguish where meaning-making is going on in terms of physics theories, models, and experimental manipulations that consist of using objects to construct events. Although ⟨gesture/body⟩ is also a crucial couplet in meaning-making, this dataset was not always filmed so that they were visible. In our third step, we build on literature on internal and external representations in order to relate these theoretical constructs with modes expressed by particular media and conceptual change in terms of physics theories, models and objects/events. We maintain that it is possible to infer particular characteristics of internal representations of learners by their performance patterns and that there is a specific relationship between internal and external representations. However, we do not propose a specific mental structure for the internal representation, nor do we describe the steps a learner goes through in creating a mental model. Rather, like Zhang (1997) we explore how “cognitive activity is distributed across internal human minds, external cognitive artifacts, and groups of people, and across space and time” (p. 180). We agree with Vosniadou (2007) in that it is not possible to conceptualize learning if not in terms of some change in what is already known, but we add that these changes occur in both internal and external representations, both while taking the individual and the group as the cognitive unit; pinpointing learning becomes a matter of perspective and granularity. In our fourth step, we consider the manner in which the kind of conceptual change we describe takes place using the notion of multimodal and multimedial reformulation. In this view, thought is constructed by and within language and interaction across talk, images, drawings, gestures, body movements and the manipulation of artifacts. We introduce three types of talk that will help us navigate through our tracking of conceptual change: object talk, tool talk and conceptual talk. The first is talk centered on objects in the experimental environment, such as batteries, bulbs and wires. The second is talk centered on the GS tool and the third is talk accounting for concepts found in the model of electricity. Finally, in our fifth step, we propose using a particular lens — the semiotic bundle (Arzarello, 2004) — for viewing as a conceptual unit the reformulations occurring between modes, media and amongst learners. A semiotic bundle is a collection of semiotic sets and a set of relationships between the sets of the bundle. A semiotic set is composed of a set of signs produced with different intentional actions, a set of modes for producing signs and possibly transforming them and a set of relationships among these signs and their meanings embodied in an underlying meaning structure. A semiotic bundle is a dynamic structure changing over time due to the semiotic activities of the participants and can be “owned” individually or by a group. Considering the studied situation, different sets of signs can be *a priori* identified, such as drawing on GS, words or gestures. In our context, a mode never changes its medium. Talk is expressed through human speech, drawings are expressed through GS and manipulations are expressed through handling batteries, bulbs and wires. This leads us to speak of ⟨mode, medium⟩ couplets. The semiotic bundle we infer from the data can be attributed either to the

group or to students, depending on the degree of collaboration among students. We note that although Arzarello's semiotic bundles are made up of an ensemble of semiotic sets (or systems), like Vosniadou, he also proposes the work of Vygotsky as a link between these sets and the human mind. Arzarello (2004) argues that "the notion of semiotic bundle properly frames the most important point in Vygotsky's analysis, namely, the semiotic transformations that support the transformation from outer to inner speech (internalization)" (p. 283).

Although the literature reviewed here is not typically seen together, we argue that the theoretical assumptions underlying each of our five theoretical constructs are compatible with one another and thus provide for a stable foundation for analyses.

Purpose of analysis

The purpose of our analysis is to track relations between and transformations of conceptual content that four students in a group express from the domain of physics as they communicate by talk, gestures, drawings in the GS interface (external representations) and through manipulations involving experimental apparatus. In other words, our goal is to track how cognitive activity moves across space and time and is distributed across the internal representations of each of our four students as we can glean them from their interactions and the external representations they work with. Our account of internal representations will be limited to their reflection through learners' actions, both talk and activity. We wish to illustrate the difficulties and competencies students have in either showing (or not) sustainable coherency of physics concepts while reformulating these concepts between all of these media.

Finding pivotal moments as a goal for analysis

Each time a given mode/medium couplet is auto- or hetero- reformulated (meaning either self- or other- reformulated) into another mode/medium couplet, it is a potential pivotal moment that may be important for conceptual change that progresses towards canonical physics because content is being transformed in one way or another. We argue for two types of pivotal moments. The first is when the semiotic bundle of either an individual or group evolves towards a structure that is progressing in its conforming to canonical physics and thus exhibiting conceptual change. The second is when the semiotic bundle reflects more complexity in terms of canonical physics while at the same time either sustaining canonical coherency (no conceptual change per se, but still sustaining coherency while augmenting complexity).

Research questions

Given all of the above, we can state three research questions. First, we wish to characterize when reformulation of conceptual content takes place across the mode/medium couplet, regardless of whether it is auto- or hetero-reformulation. Second, we wish to describe how naïve theories of physics are changed to canonical theories of physics, not only through punctual reformulation, but through the building-up of the semiotic bundle as the interaction proceeds. Finally, we expect to illustrate that some learners are able to maintain sustainable coherency of physics concepts over time while moving across mode/medium couplets whereas others have difficulties.

Basic units of analysis leading to units of interaction and to semiotic bundles

We analyze both single utterances or actions for their conceptual physics content as well as how the content of pairs of utterances and/or actions are reformulated, either by the same person (auto-reformulation) or by another (hetero-reformulation). Each utterance or action is described in the form of a particular mode and the medium used to express it. We also group together these reformulations (together with utterances or actions that have not been reformulated) across a session of work in order to form a semiotic bundle (made up of

different semiotic sets or systems). The semiotic bundle allows us to determine the state of individual student's and group's conceptualizations of physics and how they progress over time and space. Semiotic bundles are always in flux, as new sets of signs are continually being used to reflect upon content to be learned.

Representations of data and representations of analytical interpretations

Considering the theoretical perspectives we presented earlier in this section, we choose to represent our analytical work through annotated sequences of mode and medium couplets gleaned from both videos and transcriptions (e.g. talk through human voice, drawing through the GS interface and artifact manipulation through physics experiments with bulbs, batteries and wires). Annotations illustrate in what ways one mode/medium couplet is transformed into another mode/medium couplet and if talk is involved, what type of talk it is (tool talk, object talk or concept talk). Finally, we group mode and medium couplets into semiotic bundles in order to get a more global picture of individual learner's and the group's conceptualizations. Based then on what learners say and do over time and on what we know about learners' conceptions about physics, we ascertain to what extent their theories about electricity are canonical or based on everyday experience, and pinpoint pivotal moments preceding conceptual change or illustrating the sustaining of coherency with canonical physics.

Manipulations on data representations and analytical approach

As our research questions focused in part on actual talk, we could not credibly rely on the data providers' synthesis of the interaction because it summarized what the speaker said or did in the transcriber's own words, instead of the actual words of the speaker. Our analytical approach thus first consisted in obtaining more complete transcriptions from the data providers (Chen & Looi, Chapter 14, this volume), synchronizing them within Tatiana¹ (Dyke, Lund, Girardot, 2009) with the synthesis of the interaction given by the data providers as well as with the videos and the GS interface in order to replay the interaction at will, thus creating an analytical artifact. The road to a complete transcription was rocky. Chen & Looi provided two competing transcriptions that had been transcribed from two different microphones so that they differed in their accuracy and then Jeong (this section) provided a merged version of this transcription. The synchronization of this merged version and its replay was necessary in order to understand the dynamics of the interaction. However, at times the speaker was not specified in the merged version and so we needed to refer to the video to decide. There were also problems of repetition as the merged version often contained two versions of a speaker's talk (one recorded from each microphone but apparently considered to be different utterances by the person who merged the transcriptions). In order to correctly categorize the interventions (see below), at times we needed to cut them into distinct propositional units, each of which reflected a single propositional phrase during talk or a single action.

In order to understand and decrypt the interaction we performed the following steps:

1. Using the merged and corrected transcription as our data representation and replaying it with the synchronized video, we found where in the interaction the beginning and end of each drawing occurred;
2. We evaluated to what extent the drawing was coherent with canonical physics;
3. We divided the video into three episodes where different experiments of increasing complexity were performed (one battery and one bulb; two batteries and one bulb; two batteries and two bulbs). We could not always evaluate the experiments from the physics point of view because they were not always visible in the video;
4. When pertinent and possible (due to video quality), we looked at how gestures were used in the interaction in general, not the technical gestures used for manipulating objects and events, but gestures used in communicating.

¹ Trace Analysis Tool for Interaction Analysts: <http://code.google.com/p/tatiana/>

Performing these four steps allowed us to understand the interaction and to get to a point where we felt we could analyze it. We first developed our analysis of the dataset on paper and in PowerPoint before coding it in Tatiana, as we felt Tatiana was better suited to be used with a stabilized coding system than for supporting its development, although we used Tatiana in this step as a replayer.

Each intervention that we coded is defined as either 1) a propositional phrase in talk, 2) a single action in GS or 3) a moment in time during an experimental action. We speak of $\langle \text{mode, medium} \rangle$ couplets and in our context a mode never changes its medium: $\langle \text{talk, speech} \rangle$; $\langle \text{drawing, GS} \rangle$; and $\langle \text{manipulating/batteries-bulbs-wires} \rangle$. Each $\langle \text{mode, medium} \rangle$ couplet is coded in the following way:

1. Is the physics naïve or canonical? If an intervention (GS drawing or experimental action) was coherent in terms of canonical physics, it was colored white. If it was not completely coherent, it was colored grey.
2. A type of talk was chosen for each $\langle \text{talk, speech} \rangle$ couplet: tool talk (red), object talk (green), concept talk (orange). For each intervention, when there was talk about either GS (circle) or experiments (triangle), we distinguished whether the speaker was talking about his or her own action (auto or self) or an action of another hetero or other). In the former case, we put the circle or triangle in the square (talk). In the latter, we put the circle or triangle outside of the square.

Figure 7 shows a hypothetical sequence of talk. The first utterance is talk about tools (a red square), followed by a first GS drawing without talk and not compatible with canonical physics (grey circle: utterance 2). The second GS drawing is accompanied by talk about tools and not compatible with canonical physics (grey circle within a red square: utterance 3).

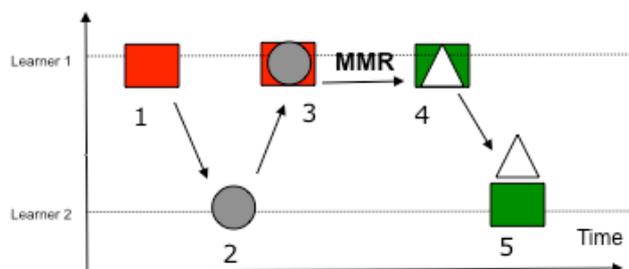


Figure 7 Example visualization based on our approach

Next, there is an experimental manipulation coherent with canonical physics (as evidenced by the bulb lighting up) where the manipulator speaks about her own manipulations of experimental objects (a white triangle inside a green square: utterance 4), followed by another correct experimental manipulation where the manipulator speaks about her partner's manipulations of experimental objects (a white triangle outside a green square: utterance 5). Rows indicate the learners where each one has his or her colored mode/medium couplets shown in a temporal line.

Such temporal visualizations (Figure 7) illustrate three phenomena: 1) whether or not and how reformulation of conceptual content takes place across the mode/medium couplet, 2) how naïve theories of physics progress towards canonical theories and 3) to what extent learners are able to reach or maintain sustainable coherency of physics concepts over time while moving across mode/medium couplets. The multimodal and multimedial reformulation (MMR) present in this diagram is between utterances 3 and 4 where Learner 1 performs a transformation from a first mode/medium couplet (GS/drawing) to a second mode/medium couplet (manipulating/batteries-bulbs-wires). We argue that each MMR forms the frontier between two semiotic bundles. The grey circle that turns into a white triangle illustrates that the physics knowledge becomes canonical during the experimental manipulation. Finally,

because the student in utterance 4 has reached a canonical understanding, the next MMRs (not shown in this short temporal sequence) should show us how the student is able to sustain this understanding, even while facing more complexity. In the next section, we illustrate how we applied this procedure to the dataset and we discuss our results.

Results

We defined three episodes corresponding to the three experiments the learners performed in which we located nine multimodal and multimedial reformulations (MMRs) that lead to either coherent or non-coherent additions to the semiotic bundle of each student or to the semiotic bundle of different incarnations of the group, depending on who was involved in the interaction at that point. For each episode, we: 1) illustrate the students' GS drawings at that point in their discussion, 2) comment a coded sequence of student and teacher talk and actions while showing where the drawing occurred and 3) provide a commented temporal visualization of our analysis. After discussion of the nine MMRs and the corresponding semiotic bundles within the three episodes, we summarize results.

Connecting a battery and a bulb with two wires: episode one

Figure 8 shows drawings done by Agnes (A1), Serena (S1) and Bruno (B1) before a particular sequence in the first episode (Table 4). Figure 9 shows Bruno's (B2) and Joel's (J1) drawing after the sequence. Agnes and Serena's drawings are correct canonical physics drawings. Bruno's first drawing (B1) is incorrect: one wire should be connected to the casing of the light bulb and the other to the end of the light bulb. Bruno corrects this in B2. However, he does not clearly show that the wire going to the minus pole of the battery actually touches the pole and does not just end at the bottom left of the battery, so we still consider it as incorrect. Joel's drawing illustrates the wire going to the minus pole a bit better.

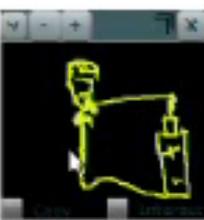
Agnes' drawing before the first sequence (A1)	Serena's drawing before the first sequence (S1)	Bruno's drawing before the first sequence (B1) and after, at line 224 (B2) —the end of MMR#2, stemming from their experiment		Joel's drawing at line 222 (J1)
				

Figure 8 Agnes', Serena's and Bruno's GS drawings before the sequence shown in Table 1 and Joel and Bruno's drawings after

Each turn in the transcription in Table 4 is coded with a type of talk and is meant to be read in conjunction with Figure 2. Turns are labeled as object talk when they deal with objects and events in the experimental field. Turns are labeled as tool talk when they refer to GS. It may seem elementary, but students talk object talk when they manipulate objects and talk tool talk when they manipulate tools. They do not speak about concepts.

Table 4 Our first sequence shows two dyads working in parallel: Serena and Agnes and Bruno and Joel; at this point, drawings A1, S1 and B2 have already been published on GS (cf. Figure 8). Parentheses signal short pauses; Singlish (e.g. leh, mah) interpreted according to <http://en.wikipedia.org/wiki/Singlish>; overlap not transcribed. This part of the transcript is not included in the dataset given by Chee Kit & team.

N°	Part.	Talk	Type of talk
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202	Bruno	ok () ok you put it at the bottom cause just now you were on the table	object talk
204	Bruno	ok then put it on top put it on top	object talk
205	Bruno	ok then let's write the answer la	tool talk
206	Agnes	aiyer cannot connect that one cannot play leh no fair	object talk
207	Bruno-	so there's the minus	tool talk
208	Joel	no cannot write the answer first do the draft first	tool talk
209	Bruno	where's the pen where's the pen	tool talk
210	Joel	we're doing the draft first mah	tool talk
212	Serena	one at the bottom one at the side	object talk
213	Agnes	i know there	object talk
214	Serena	ei got got light already got light already	object talk
219	Bruno	object which one is the one for drawing	tool talk
222	Joel	you haven't changed the color	tool talk
224	Bruno	oh no wonder it's black and black	tool talk

In this sequence, there are two simultaneous discussions taking place: one between Agnes and Serena (in bold) and the other between Bruno and Joel. Figure 9 shows a representation of these discussions that can be linked back with line numbers to the transcription in Table 4. In Figure 9, the X-axis shows time, although not proportionally. Participants are on the Y-axis, each on their own line. Thin arrows going from one utterance or action to another indicate sequentially occurring talk/action. But sequentially occurring talk/actions from a chronological standpoint does not necessarily mean adjacency pairs (Schegloff & Sacks, 1973) or sequences of meaningful talk. The sequences and figures we show will not always have all turns noted because some turns were duplicates for the reasons explained previously. During the sequence in Figure 9, Agnes and Serena are connecting a bulb to a battery, based on their canonical GS drawings (white circles). Squares signify talk and triangles signify experiments. The experiment succeeds (the bulb glows) — i.e. represents canonical physics — and so the triangle is white (214). The triangles are within green squares where green represents talk about objects in the experimental field (206, 212, 213, 214). Triangles or circles within squares mean that the talk is a reference to ones own talk or actions; this is often only verifiable in the video. For example, in 206, Agnes is talking about the wires she is connecting herself.

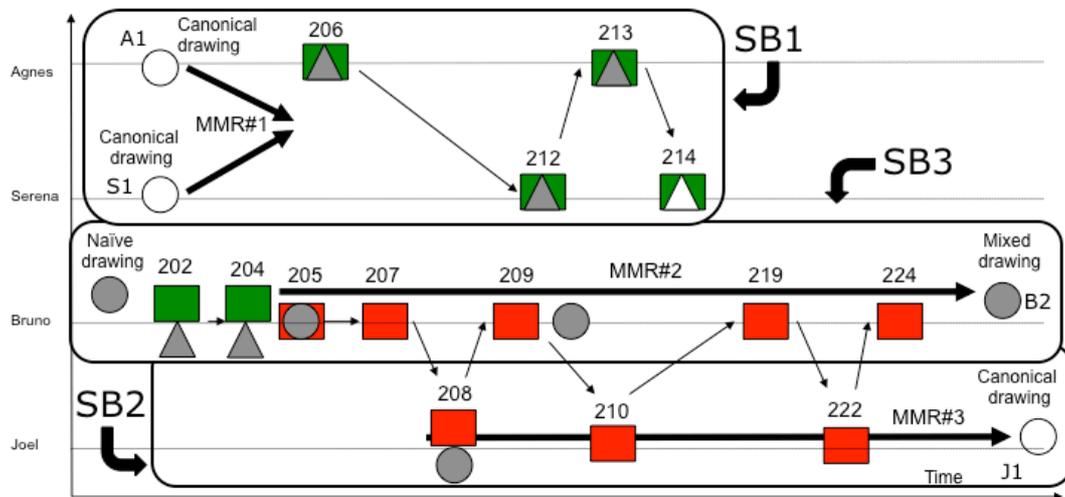


Figure 9 A temporal visualization of a sequence from episode one

It seems evident from the transcription and from viewing the video, that each understands the other's actions. We argue that what we call Agnes and Serena's coordinated 4-handed experiment is a reformulation from $\langle \text{drawing/GS} \rangle$ to $\langle \text{manipulating/batteries-bulbs-wires} \rangle$. Let's call this multimodal and multimedial reformulation MMR#1 (cf. Figure 9). MMRs are illustrated by thick arrows. The construction of this MMR leads to the first semiotic bundle (labeled SB1 in Figure 9) that integrates talk about drawing with GS, drawings A1 and S1 as well as the objects that Agnes and Serena manipulate together. Agnes and Serena share this semiotic bundle. The two girls sustain coherency with canonical physics during the construction of their semiotic bundle despite performing a complex transformation between mode/medium couplets. Students do not always succeed at such transformations and indeed, success is rather the mark of a competent student or expert (Kozma, 2003; Lund & Bécu-Robinault, 2010).

In the second parallel interaction thread Bruno and Joel are talking together and trying to connect the circuit with a battery, bulb and wires. Bruno has already drawn his circuit on GS, but Joel has not. Unfortunately, we do not see how they attempt to connect the circuit because they are filmed from behind without a view on the experiment. As before, squares signify talk and the color green signifies that talk is about objects in the experimental field. The triangle signifies objects or actions taken in the experimental field. Bruno is speaking about Joel's actions in the first two utterances in regards to the experimental field (202, 204), so the triangles are outside of the squares. Next, Bruno proposes to redo the drawing in GS and searches for how to erase part of his drawing (205). This part of the interaction is represented by a square because it's talk, and it is red because Bruno is talking about GS tools (tool talk). The circle is inside the square because he is talking about his own action and it is grey because he is referring to changing his drawing and his drawing is only partly coherent (see below).

After more talk (207, 209, then 219, 224), Bruno redraws the wire (grey circle) that leaves the minus pole so that it connects to the bulb's casing, instead of to the bulb's endpoint (as in his previous drawing). However, it still is not clear that Bruno has identified the minus pole of the battery because the wire could be hooked only to the corner end of the battery and not to the pole on the middle of the battery's end. The drawing is grey (B2 in Figure 8 and Figure 9) because part of it respects canonical physics and part does not. On the other hand, Joel does a GS drawing (J1 in Figure 8 and Figure 9) that is clear and completely coherent (white circle), both in terms of battery pole and bulb poles. Note the difference between Bruno's second drawing and Joel's first drawing in terms of how the wire leaves the minus pole of the battery

(compare them in Figure 8). Both boys reformulate from ⟨manipulating/batteries-bulbs-wires⟩ to ⟨drawing/GS⟩. Let's call these respectively MMR#2 (Bruno) and MMR#3 (Joel) — cf. Figure 9. The construction of these MMRs lead to the two next semiotic bundles SB2: talk during manipulation of objects between Joel and Bruno, J1 drawing, attempts to connect wires and battery and bulb; and SB3: talk about objects with Joel after posting B1 and with the girls after Bruno posts B2, B2 drawing, successful connection of one battery, one bulb and one wire. SB2 is Joel's semiotic bundle and SB3 is Bruno's. Both are labeled in Figure 9.

At this point in the interaction, three out of the four students have completed a coherent drawing. Only Bruno does not exhibit sustainable coherency during semiotic bundle construction while reformulating between mode and medium couplets. However, none of the students make reference to physics concepts throughout this sequence or at any other time in the corpus. Thus, even if on the surface they succeed, we may question their ability to understand the physics concepts behind their drawings and their experimental manipulations.

Connecting two batteries and a bulb: episode two

In a second sequence from episode two, all four students are interacting, mostly trying to connect two batteries together with wires to a bulb. Before this sequence, Bruno posted two drawings (B2 and B3) into the public space. In the drawing representing the experiment with two batteries (B3), the minus signs are drawn, but he shows the same ambiguity as he did for B2 in regards to connecting the wire to the actual minus pole in the middle of the battery and not just to the bottom corner of the battery. In addition, his possible attempt at modeling a parallel circuit with the batteries (B3) is not successful; the batteries are not connected together so that current flows. Bruno's model of the new experiment (B3) is thus not coherent with canonical physics, but he has nevertheless performed a second MMR (MMR#4 — cf. Figure 10). He performs a transformation from ⟨manipulating/batteries-bulbs-wires⟩ to ⟨drawing/GS⟩. The construction of MMR#4 leads to the construction of Bruno's SB5 (done in parallel to SB4 — see below). SB5 consists of talk (sequence not shown; occurs before that in Table 5) with others during the manipulation phase, drawing B3 and a successful connection of one battery, one bulb and one wire. We note that although Bruno's drawing B3 represents two batteries, he is only experimenting with one, which may illustrate his current incapacity to sustain coherency with canonical physics. SB4 — shared by Agnes, Serena and Joel — is a reconfiguration of SB1 and SB2 while also integrating a second battery. SB4 is the only example of a semiotic bundle that is not produced by an MMR. Rather it contains all the elements of the previous semiotic bundles (SB1 and SB2), but also adds an extra battery.

Bruno's second drawing (B2)	Bruno's third drawing (B3) — end of MMR#4 leading to SB5	Agnes begins drawing in Bruno's space (A2) — end of MMR#5	Serena shows drawing from another group (G _S)	Bruno finishes the drawing Agnes began (B _{A2}) — end of MMR#6
				

Figure 10 Bruno's publicly posted drawings, going into the second sequence of episode two; the drawing Agnes begins in Bruno's space; the drawing that Serena notices in another group, and how Bruno finishes the drawing Agnes begins in his space

In this second sequence (cf. Table 5), not all turns are represented, as explained previously. Students talk object or tool talk with no discussion about concepts such as poles or current. We will return to this observation in the conclusions.

Table 5 Sequence showing the students first working together to hook two batteries to one bulb, then Agnes and Bruno exchange about Bruno's GS drawing and finally, Serena brings everyone's attention to a drawing she found on another group board. A2 was posted at 15:03 in the dataset provided by Chee Kit & team.

N°	Partic.	Talk	Type of talk	GS Drawings
380	Bruno	worked out already heh heh posted already	tool talk	B2,B3 been posted
381	Serena	we got () we got four wires leh	object talk	
382	Bruno	never mind just cancel oh I know put here easier	tool talk	
385	Agnes	just do another one la	tool talk	
386	Teacher	now () maximum two batteries	object talk	A2 posted here
387	Serena	maximum two batteries leh Bruno	object talk	
388	Friend	no i know put this here	object talk	
394	Joel	then then one () one here one here	object talk	
396	Agnes	bruno you draw the rest	tool talk	
408	Joel	it's not connected to the light bulb	tool talk	
409	Agnes	bruno bruno you draw finish () draw finish	tool talk	
413	Bruno	() cancel this one	tool talk	
415	Joel	() already finish drawing	tool talk	
416	Agnes	bruno, you draw finish ah	tool talk	
420	Agnes	and this one.	tool talk	
421	Serena	[to the rest] we all try this one. () we all try this one	tool talk	Shows other group's GS

After having noticed that Bruno's drawing (B3) is incorrect, Agnes begins a correct one in his GS space and tells him to finish it ("Bruno, you draw finish draw finish": turns 409, 416). This is MMR#5, represented by A2 in Figure 10 Agnes' talk is about tools all along the sequence (red squares in 396, 409, 416 and 420); the circle represents GS; the ones in 396, 409 and 420 are outside the square because Agnes is taking about Bruno's drawing and they are grey because the drawing is not finished so we can't decide if it respects canonical physics (white) or not.

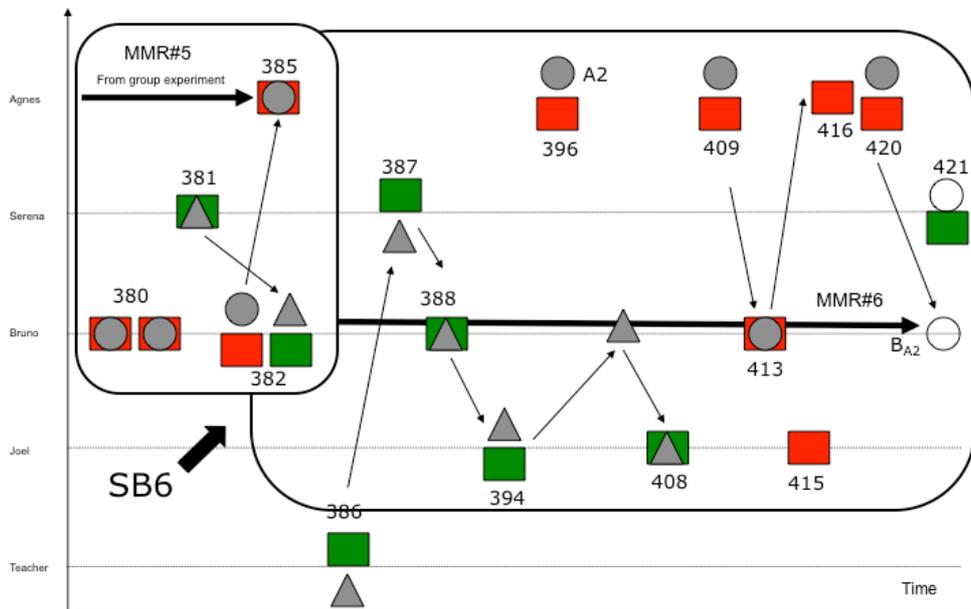


Figure 11 A temporal visualization of a sequence from episode 2

Bruno finally agrees to follow Agnes' directions (no corresponding talk), finishes the drawing correctly and posts it. Let's call this MMR#6 (labeled in Figure 10 and Figure 11; it occurs after the sequence in Table 5 ends). It is distinguished from the others in that it is cooperative: begun by one person (Agnes) and finished by another (Bruno). In other words, in this sequence (Table 5 and Figure 11), Agnes reformulates from \langle manipulating/batteries-bulbs-wires \rangle to \langle drawing/GS \rangle , a drawing that Bruno later finishes, although we consider that his MMR reformulates from \langle manipulation/batteries-bulb-wires \rangle to \langle drawing/GS \rangle : it's the shared experiment that allows Bruno to complete Agnes' drawing. Figure 10 (far right, B_{A2}) shows that Bruno added labels to the poles of both batteries (- and +), and then drew a wire from the plus side of the second battery to the endpoint of the bulb. Note that the batteries are now clearly connected serially, contrary to his drawing (B3). At this point, both MMR#5 and MMR#6 help Bruno to build semiotic bundle SB6 (labeled in Figure 11): talk about ways to handle the objects (turns 386-394), drawing BA2 (turns 385, 396, 409, 416), successful connection of two batteries, two wires and one bulb (previous turns not shown). Like the first sequence, students only talk about tools and objects, not concepts. However, contrary to the first sequence (two parallel discussions), here the students are exchanging more and moving a bit more between GS tool and objects.

Connecting two batteries, two bulbs and two wires: episode three

In the continuing interaction — still shown at the very end of turn 421 and Figure 11 — as Bruno finishes up the drawing Agnes began, Serena turns around her pivot-screen to show her GS public space to the others in her group (see also Figure 12, left).



Figure 12 Serena shows the members of her group another group's drawing and her group decides to perform a new experiment. This episode ends with MMR#7, represented above right, when the students light the two bulbs with two batteries (and this results in SB7)

<p>Agnes does the drawing to the right on Bruno's GS after the experiment (B_{A3}),</p>		<p>Serena notices the drawing on the right from another group (G_S)</p>		<p>At the end of the sequence, Agnes draws what looks like two batteries and two bulbs (on right), but her wire connections are not clear ($A4$)</p>	
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Figure 13 Agnes draws on Bruno's GS, Serena notices another group's drawing and Agnes draws her group's experiment

This moment is interesting because of Agnes' drawings (she draws B_{A3} during the talk in Table 6). She enlarges her semiotic bundle while sustaining coherency with canonical physics. Indeed, when the environment changes, Agnes is able to adapt her understanding of how a circuit functions and integrate this into her semiotic bundle. She appropriates as her own and integrates two mode/medium couplets: 1) a new GS drawing (the one Serena shows to the group: G_S) and 2) corresponding experimental actions, both being compatible with previous elements she has already integrated. Her performing this integration does not seem to modify the coherency she has already built, and enables her to reformulate the experiment done by the others with her drawing $A4$.

Table 6 Sequence where Agnes draws in GS (cf. Figure 13 on left, published at the time of line 554), the others look at other students' productions and manipulate the batteries, bulb and wires. B_{A3} is not referred to in the common transcript provided in the dataset chapter, as it occurs later.

N°	Partic.	Talk	Type of talk	GS Drawings
536	Agnes	i draw the first method ah	tool talk	
537	Joel	we can test we can test out more	object talk	
538	Joel	() like that can () no	tool talk	
543	Serena	you all () you all try other ways	tool talk	
544	Friend	cannot this one lighted	tool talk	
546	Serena	you know why it's the same battery	tool talk	
553	Friend	you want to take another wire	object talk	
554	Joel	() arrow () take two () where's the other black wire	object talk	B_{A3} posted

MMR#7 is *collective* in that it starts with the Drawing/GS couplet (turn 421, Table 5) that Serena shows the group (we argue that it is *appropriated* by the group members) and it ends with \langle manipulating/batteries-bulb-wires \rangle , carried out by Joel, Bruno, Agnes and Serena (cf. Figure 12 right). It is not Serena's drawing, but the MMR is still performed from this other group's drawing. The construction of MMR#7 leads to the seventh semiotic bundle SB7, shared for the first time by all participants: Agnes, Serena, Joel and Bruno. SB7 is constructed simultaneously with SB8 and consists of talk concerning comparison of events with one or two batteries, the GS drawing from another group that Serena shows to the group and the two batteries connected to one bulb (sequence not shown). MMR#8 occurs when Agnes transforms the group's \langle manipulating/batteries-bulbs-wires \rangle to \langle drawing/GS \rangle on Bruno's GS

(B_{A3} in Figure 13 and Figure 14). Figure 14 shows the talk around the multimodal and multimedial reformulation that the group performs (turns 536-554) and the two multimodal and multimedial reformulations that Agnes performs (MMR#8 and MMR#9). SB8 is also shared by all participants and consists of talk about handling devices (turn 537), drawing B_{A3} (turn 536) and the manipulation of two batteries connected to one bulb (turns 553-554). MMR#9 occurs when Agnes begins with the group’s manipulating/batteries-bulbs-wires couplet and ends with a drawing/GS couplet (A4 in Figure 13 and Figure 14). SB9 is also shared by all participants and consists of talk (sequence not shown) about ways to handle batteries, bulbs and wires, the drawing A4 and the manipulation of 2 batteries, 2 wires and 2 bulbs. Yet again, in this third sequence, students only speak about tools and objects and not concepts.

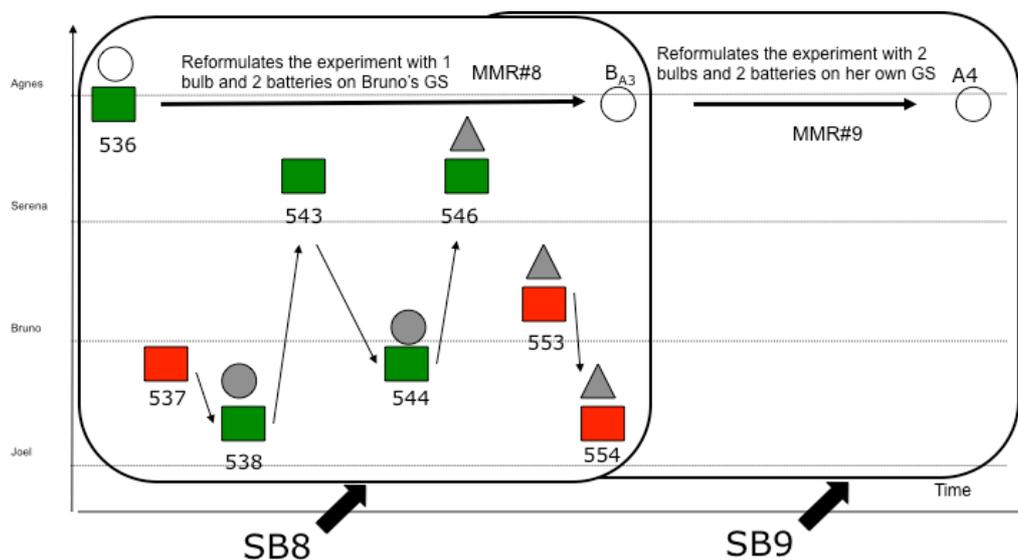


Figure 14 A temporal visualization of a third sequence from episode three

Synthesis of results

Table 7 describes our synthesis of MMRs and semiotic bundles (SB); it begins with the MMR#, then specifies the drawing as referenced in this chapter, describes the beginning and ending MMR couplet, gives the number of the SB, evaluates its state (coherent, incoherent in terms of whether or not the physics is correct) and finally lists the SB owners. There are four individual SBs (2,3,5,6) and six collective (1,4,6,7,8,9).

Table 7 Synthesis of MMRs and the semiotic bundles they participate in constructing; MMRs 4, 5 and 6 appear in the shared transcript and the corresponding timestamps are shown in the far left column

MMR#	GS#	Departing MM couplet	Arriving MM couplet	Semiotic Bundle#, state of and owner
1	A1 & S1	Drawing/GS	Manipulating / Batteries-bulb-wires (BBW)	SB1, coherent, shared by Agnes and Serena
2	B2	Manipulating / BBW	Drawing/GS	SB3, probably incoherent, Bruno
3	J1	Manipulating / BBW	Drawing/GS	SB2, coherent, Joel
4/12:38	B3	Manipulating / BBW	Drawing/GS	SB5, incoherent, Bruno
				SB4 (contains elements of SB1 and SB2 + an extra battery), Agnes, Serena, Joel

5/14:28	A2	Manipulating / BBW	Drawing/GS	Coherent as MMR#5, but not finished
6/15:45	B _{A2}	Manipulating / BBW	Drawing/GS	SB6, probably coherent, Bruno
7	G _S	Drawing/GS	Manipulating / BBW	SB7, coherent, all participants
8	B _{A3}	Manipulating / BBW	Drawing/GS	SB8, probably coherent, all participants
9	A4	Manipulating / BBW	Drawing/GS	SB9, coherent, all participants

Figure 15 synthesizes the three episodes referred to in our results. Each square is a semiotic bundle (SB) incorporating talk, drawings, and experimental objects. Analyses show two MMR types: from drawing/GS to manipulating/batteries-bulbs-wires and the reverse.

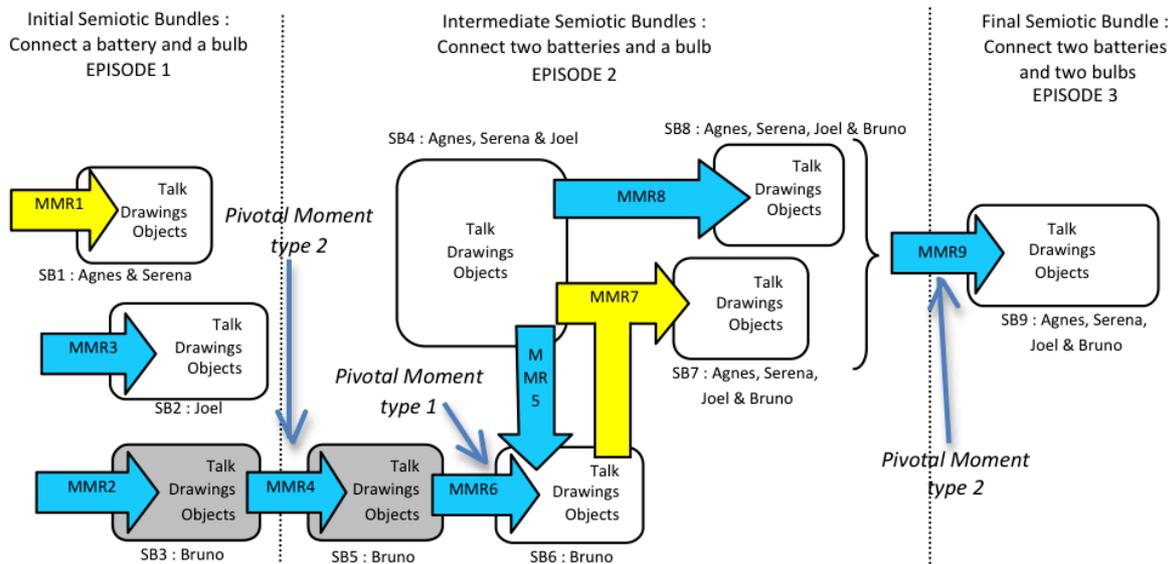


Figure 15 The boxes represent the semiotic bundles built by the students. Boxes are grey if the semiotic bundle is not totally coherent with physics. Boxes are white if the semiotic bundle is coherent with physics. In yellow we represent multimodal and multimedial reformulations from drawing/GS to manipulating/batteries-bulbs-wires. In blue we represent multimodal reformulations from manipulating/batteries-bulbs-wires to drawing/GS.

Figure 15 represents the evolution of the individual student's and group semiotic bundles (SB). There are nine SB's. A snapshot of our analysis of the SB is taken at each MMR, shown here in succession. The students who participated in the interaction at that point are listed as "owning" that particular SB at that moment. We argue that the MMRs are partly responsible for the semiotic bundles' evolution as they can illustrate moments of conceptual change (pivotal moment type 1), but also increasing levels of complexity (pivotal moment type 2) without giving up coherency with canonical physics.

At the top left of Figure 15, we argue that Agnes and Serena use MMR#1 to establish a semiotic bundle concerning the way to connect a bulb to a battery (SB1). Joel does not reach a semiotic bundle coherent with canonical physics until after MMR#3 (SB2) whereas Bruno's production, even after MMR#2, is still not coherent with canonical physics (SB3). We have seen that Bruno's misunderstanding disrupts him as he tries to connect two batteries to a single bulb (i.e. he has still not identified that minus poles and plus poles should be connected so that current flows). He is thus not able with MMR#4 to build a semiotic bundle coherent with canonical physics (SB5). Bruno is only able to build a coherent semiotic bundle with the help of Agnes' MMR#5 (SB4), when he performs MMR#6 (SB6), continuing the multimodal and multimedial reformulation initiated by Agnes (ending with B_{A2}).

From this point, the group seems to share the same semiotic bundles (cf. Figure 15). As Serena shows a new drawing on her GS, the whole group starts a collaborative experiment producing the collaborative MMR#7 (SB7). This reformulation from drawing to manipulating enables the whole group to integrate in their shared semiotic bundle the connection of two bulbs to two batteries, respecting canonical physics. MMR#5 compared to MMR#7 is important from a learning perspective. Indeed, the students navigate between the electric devices to their GS drawing, which implies modeling activities including physics knowledge. These modeling activities reveal relationships among the semiotic sets, which reinforces the semiotic bundle coherence. This coherence, respecting canonical physics, is shown to be sustainable with MMR#9 as coherence remains despite the increase in complexity (SB9). Right before this, Agnes takes the responsibility of drawing, with MMR#8, the experiment performed by the group. No one questions this reformulation, which thus seems to obtain the tacit agreement of the group. The semiotic bundle of the group is enlarged to become SB8, due to integrating a new way to connect the battery and bulb and of because of its drawing.

The group then starts a new experiment with two bulb and two batteries. As soon as the bulbs light, Agnes reformulates this experiment (MMR#9) with a new drawing. This leads the group to build the last common semiotic bundle SB9, which integrates all the previous elements, as well as the method to light simultaneously two bulbs with two batteries.

Pivotal moments and sustainable coherency

Earlier in this chapter, we postulated that each time a given mode/medium couplet is auto- or hetero- reformulated into another mode/medium couplet, it is a potential pivotal moment that may be important for conceptual change because content is being transformed. We argued for two types of pivotal moments. The first was when the semiotic bundle of either an individual or group evolves towards a structure that is progressing in its conforming to canonical physics and thus exhibiting conceptual change (i.e. Bruno's MMR#6). The second was when either an individual's or group's semiotic bundle reflects more complexity in terms of canonical physics while at the same time either sustaining canonical coherency or progressing towards canonical coherency. The MMRs that satisfy this definition of being pivotal are MMR#4 and MMR#9. MMR#4 is found at the frontier of episode 1 and 2 (cf. Figure 15) where complexity is increased by connecting two batteries instead of one to the bulb. MMR#9 is found at the frontier of episode 2 and 3 (cf. Figure 15) where complexity is again increased by connecting together two batteries and two bulbs. MMR#4 maintains its coherency with canonical physics whereas MMR#9 progresses partially towards canonical physics (i.e. Bruno correctly draws the batteries, but not how the poles should be connected).

Conclusions and Perspectives

Our first research question sought to characterize when reformulation of conceptual content took place across the mode/medium couplet, regardless of whether it is auto- or hetero-reformulation. This distinction was important for deciding whether or not a MMR was individual or collective and thus to see when semiotic bundles were shared. We characterized nine instances of multimodal and multimedial reformulation in the three episodes that we studied. Second, we sought to describe through pivotal moments how naïve theories of physics are changed to canonical theories of physics, not only through punctual reformulation, but through the building-up of the semiotic bundle as the interaction proceeds. We identified three pivotal moments that either illustrated conceptual change (MMR#6) or showed how students' physics knowledge remained canonical (#MMR4) or progressed in respect to canonical physics (MMR#9) despite an increase in complexity (e.g. moving from episode 2 to episode 3). Third, our results show that some students can increase complexity while maintaining coherency (Agnes, Serena) while others have difficulties (Bruno).

In conclusion, although students were mostly likely not conscious of this fact, the pedagogical situation that gave rise to the dataset studied for this chapter gave them the opportunity to test the robustness of their conceptions about electricity. If they were able to perform successful multimodal and multimedial reformulations across couplets of ⟨talk, speech⟩, ⟨drawing, GS⟩ and ⟨manipulations, batteries, bulbs, wires⟩ and thus build coherent semiotic bundles, they thus illustrated their robust canonical knowledge of physics. If they had difficulties, then perhaps the reformulations they were required to do helped them progress from naïve physics to canonical physics, as in the case of Bruno correcting his drawing after having done the experiment with Joel. A next step could be to reflect more generally on how methods and tools in pedagogical situations could help learners to develop such sustainable coherency, especially if the pedagogical situation could be structured so that student talk centered more on concepts, rather than only on objects and tools.

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Context sensitive ‘how’ explanation in children’s multimodal behaviour

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Abstract

In this paper we describe how pragmatic constraints of two types of explanatory interactions influence both the organization of syntactic elements in clauses and gestural behaviour. We provide evidence on how young children confronted with a dual-goal task including both a referential issue and a social interactional issue start to show competencies that are not present in a single referential task. Further, our intention is to contribute to theoretical issues in pragmatics through a study of how children mobilize pragmatic constraints of language production and also to account for language development within the framework of it being understood as a multimodal phenomenon.

1. How does context influence language production and understanding?

It may seem obvious to state that characteristics of human communication are influenced by the context in which such communication occurs, but context is a problematic concept to define (Duranti & Goodwin, 1992). Research in Conversation Analysis and Interactional Linguistics (i.e. the study of grammar in interaction) and in particular, video analyses of talk-in-interaction, focus on specific aspects of context in which language is produced as their goal is to “investigate the procedural bases of reasoning and action through which actors recognize, constitute and reproduce the social and phenomenal worlds they inhabit (Goodwin & Heritage, 1990, pp. 286-287).” Here, gesture, posture, gaze, pauses and manipulation of resources — are all viewed as meaning carrying elements of how the interaction is organized and coordinated by the participants (e.g. Goodwin, 1986; Kendon, 2004).

In this paper, we constrain the definition of context in a way that is compatible with our own overarching goal and that is to compare two pragmatically different situations in which children give “how” explanations. Our approach is original in that we aim to describe how pragmatic constraints of two types of explanatory interactions influence the organization of syntactic elements in clauses as well as gestural behaviour. More precisely, we provide

evidence on how young children confronted with a dual-goal task including both a referential issue and a social interactional issue show competencies that are not present in a single referential task. Further, our intention is to contribute to theoretical issues in pragmatics through a study of how children mobilize pragmatic constraints of language production and also to account for language development within the framework of it being understood as a multimodal phenomenon.

2. On contextualized multimodal explanation in children

Gesture, gaze and the interplay between language, deixis and other types of gesture in everyday social interaction have been studied extensively since Goodwin (1981) and Kendon's (1990) pioneering work. Today we have at our disposal a substantial volume of observation on pointing and gaze (Kita, 2003; Mondada, 2009), hand gestures (Calbris, 2012; Kendon, 2004), head gestures (McClave, 2000), emblematic gestures (Brookes, 2004), and use of gesture in more specific contexts such as the classroom (e.g. McCafferty & Stam, 2008). In addition, gesture use and multimodal means for communication and mutual understanding were studied in the context of more specific discourse genres such as the narrative in adults (McNeill, 1992; Bouvet, 2001) as well as in children. Children aged 9 years and over were found to rely more on gesture and gaze resources and to deliver truly embedded narratives, i.e. narratives introduced and commented on during the interaction process, with the child acting as a genuine narrator instead of barely recounting facts and events he witnessed (Colletta, 2009). These results were later replicated for French (Colletta, Pellenq & Guidetti, 2010) as well as for other languages (Graziano, 2009; Kunene, 2010). Altogether, the study of children's narratives indicates a strong and enduring relation between language and gesture throughout the child age span (Alibali, Evans, Hostetter, Ryan, Mainela-Arnold, 2009; Laurent, Nicoladis & Marentette, 2013).

Another discourse genre for which multimodal aspects of communication and mutual understanding were studied is explanation. Lund (2007) focused on the specific pragmatic roles that gaze and gesture play in interactive face-to-face explanation between pre-service teachers studying filmed interactions of students in the classroom. The work of Lund & Bécu-Robinault, (2010) also illustrated the differences in how expert teachers and novice students reformulate physics knowledge across talk, gestures, drawings and manipulations of resources during their explanations. Similarly, Goldin-Meadow and her collaborators studied children's use of gesture in the resolution of problem solving and mathematic tasks (Goldin-Meadow, 2003). They showed how children use gestures in their explanations and how other children can interpret these gestures. In addition, Colletta and Pellenq (2009) studied explanations produced by French children aged 3 to 11 years. In their study, all explanations were formulated by children in response to a 'why' question. The authors analysed the formal aspects of the explanations and found an increase in all observed measures: duration, number of syllables, number of clauses, use of connectives and use of co-speech gestures. The results provided strong evidence for the existence of developmental changes affecting the multimodal construction of explanations. More recently, a study by Reig Alamillo, Colletta & Guidetti (2013) complemented these findings by analysing explanations produced by French children and by comparing this type of discourse with narratives produced by the same group of children. The task (explanation vs. narration) also had effects on the use of both language and gesture: gestures and subordinate markers were more frequent in explanations than in narratives, whereas cohesion markers were more often used in narratives. Finally, Mazur-Palandre & Lund (submitted) analysed verbal and gestural behaviour of 6 year-old children during explanation of on-line educational games. They focused on the communication behaviour of child-instructors explaining two games to child-learners in either one of two conditions: 1) where both of the role-playing children could see each other and 2) where a

curtain separated them. Gesture and clause profiles depended on both context of production (which game was played) and communicational situation (the explainer's addressee was visible or not) (cf. also Mazur-Palandre & Lund, 2012). Here again, multimodal language production was found to be closely tied to context.

In this paper, we present a follow up study aimed at examining in greater detail the way contextual constraints find their expression in children's gesture and speech. In the aforementioned studies, contextual constraints either appeared in monologue-type tasks with an adult monitoring the answer-giving or in dialogue tasks with the child doing the monitoring. A general assumption in the study of child language puts narrative production as a later language acquisition than conversation abilities. However, everyday dialogue greatly varies according to its inherent constraints. Many types of finalized dialogue involve several pragmatic constraints, e.g. monitoring social interaction while handling a monologue-type task such as reasoning, explaining or narrating. Can we find specific indicators that illustrate children's competency in such complex communication tasks? How do pragmatic constraints shape their language and gesture behaviour? As far as we know, this issue remains largely unstudied.

3. Method

3.1 Research questions and hypotheses

In order to find some answers to the above questions, we gathered data on two distinctive types of 'how' explanations. As a discourse genre, the 'how' type of explanation is interesting to investigate compared to the 'why' type of explanation. The 'why' type of explanation, also named 'causal' explanation, is a type of expository discourse (Nippold & Scott, 2009) that links an *explanandum*, i.e., a phenomenon or behaviour to be explained, to an *explanans* or cause, reason, or motivation for this phenomenon or behaviour (Hempel & Oppenheim, 1948; Veneziano and Sinclair, 1995). At the structural level, causal explanations necessarily link two sequences in the textual form < P because Q > (Grize, 1990; Adam, 1992). In contrast, the 'how' type of explanation is more closely related to depiction rather than to expository discourse (Adam, 1992). As a discourse genre and in the same way as depiction, 'how' explanation is less formally structured and is more dependent on reference features. As a consequence, there are several kinds of 'how' explanation'. In this study, we considered two kinds of 'how' explanations:

- 'process' explanation (hereafter referred to as PROCESS-EX): depiction of a set of actions leading to some result,
- 'instructional' explanation (hereafter referred to as INSTRUCT-EX): formulation of a set of instructions leading to some result.

We selected these two types of 'how' explanation as they show some strong differences. PROCESS-EX is fundamentally a monologue-type of discourse act: it does normally answer a 'how' question such as "how did this happen", but subsequently, all a speaker needs to do is coherently build reference in order that the explanation succeed as a discourse act. In contrast, INSTRUCT-EX is fundamentally a dialogue-type of discourse act: it normally responds to a "how shall I proceed?" request from the interlocutor. To succeed as a discourse act, the speaker must both coherently build reference *and* monitor the interactional process with his or her addressee. Consequently, these two contexts differ in their inherent pragmatic constraints: both involve referential constraints, yet only instructional explanation involves interactional (i.e. joint-action) constraints.

Contrasting these two types of 'how' explanation allows the study of how pragmatic constraints find their expression in language and gesture. In the study we detail here, we

investigate whether young children confronted with a dual-goal task including both a referential issue and a social interactional issue show competencies that are not present in a referential task without a social component. Our hypotheses are as follows:

- Hypothesis 1. Young children aged 6 years show competencies related to a dual-goal finalized dialogue task;
- Hypothesis 2. At this age, a dual-goal dialogue task is more difficult than a single goal monologue task;
- Hypothesis 3. Pragmatic constraints are separately definable for each task and are illustrated in both in language and gesture;
- Hypothesis 4. Young children adapt their use of gesture resources to accomplish the task.

3.2 Population

In order to investigate the way children integrate various constraints and communicate accordingly using gesture and language resources, we compared two populations of two different studies. In the first study on INSTRUCT-EX, 60 French monolingual children participated and half of the children explained two video games to the other half of the children. In the second study on PROCESS-EX, 41 French monolingual children participated and gave an answer to a “how did this happen” prompt after viewing a short cartoon video clip. All participants were first graders attending primary schools with similar social and environmental characteristics. All children were French native speakers from the Rhône-Alpes region in France. They were non-bilingual and did not have any behavioural or learning problems. Each child was authorized by his/her parents and participated on a voluntary basis. We filmed all students from both schools during regular classroom hours inside their school buildings, in a separate room in order not to disturb ordinary classroom work.

From the entire set of data, we extracted 15 INSTRUCT-EX from study 1 (mean age 6.6 years, age range 6.4-7.2 years) and 15 PROCESS-EX from study 2 (mean age 6 years, age range 5.7- 6.4 years). We excluded from analysis all explanations produced by children who would not complete the task as well as explanations from children who did not produce any co-speech gesture. Explanations were selected on the basis of age in order to find the best match between the two populations.

3.3 Procedure

In study 1, all children played two games from a French on-line educational game site (www.cognik.net): (a) a numbers game in which the player is asked to recognize numbers or count objects by clicking on the correct image and (b) a spatial game in which the player must hit back a ball with the help of a kind of racket, and in doing so break bricks.

Children worked in pairs that were constituted by their teacher, according to the criteria of being able to work well together. Teachers also assigned a role to each child: child-instructor or child-learner. The experiment was divided into three phases. The child-instructor was first asked to play a game (either the numbers or spatial game) in order to explain it to a peer (phase 1). Once the child-instructor finished the game, the experimenter brought in the child-learner and the child-instructor explained the game to the child-learner (phase 2, INSTRUCT-EX — the focus of half of our analyses for this article). Next, the child-learner played the game under the watch of the child-instructor; the latter was instructed to help the former if need be (phase 3). The experiment took place during two weeks (A and B). Game playing was counter-balanced between week A and week B.

In study 2, all children participated in a developmental and comparative study. A narrative task and an explanatory task were administered in the same session and were based on a 2 minute 43 second clip of a Tom & Jerry cartoon shown to the participants on a laptop computer. In the story, a mother bird leaves her egg in the nest. The egg accidentally falls out and rolls into Jerry’s house. The egg hatches in Jerry’s house and a baby woodpecker emerges. The baby bird then starts damaging Jerry’s furniture. After a few failed attempts to

calm the bird down, Jerry gets angry and decides to put the bird back in its nest. The narrative task was proposed first: every child was asked to tell the story he or she had just seen to an adult sitting next to him/her. Immediately after, the experimenter told the child that he was going to ask him or her some questions, and asked the following: 1. Why does the mummy woodpecker leave the nest? 2. Why does the egg end up in Jerry's house? 3. Why is the baby bird pleased to see Jerry? 3. Why does Jerry take the baby back to its nest at the end of the story?

All questions and answers were videotaped. However, for this study, we extracted answers to the second question which corresponds to a "how did this happen" question (how did it happen that the egg ended up in Jerry's house?) and that elicited a PROCESS-EX.

3.4 Transcription and coding

The data was entirely transcribed and annotated using ELAN software (<http://www.mpi.nl/tools/>) using an annotation scheme adapted from Colletta, Kunene, Venouil, Aurélie, Kauffman & Simon, 2009. The annotations provided information on syntax, lexicon, discourse and co-speech gestures.

Speech transcription and coding

The speech transcription and annotation conventions were adapted from the CHILDES (<http://childes.psy.cmu.edu/>) and VALIBEL (<http://www.uclouvain.be>) conventions.

The speech was first segmented into clauses, and the number of clauses was counted. Number of clauses as a measure of the length of the linguistic productions was used instead of sentences or utterances. Sentences are a more suitable descriptive unit for written texts whereas the term 'utterances' has too imprecise a definition to be fruitfully used in corpus annotation coupled with quantitative analysis. The clause has been shown to capture the basic semantic configuration in which language operates (Gineste & Le Ny, 2002), indeed "*the clause is the grammatical unit in which semantic constructs of different kinds are brought together and integrated into a whole*" (Halliday 1989: 86).

The **clause count** allowed us to estimate the length of explanations. Besides, as explanations varied in length and content from one child to another, all subsequent measures were based on the **rate per clause** in order to compare both types of contexts and explanations.

Considering our hypotheses, we had to code for linguistic variables that would index: (a) the referential constraints proper to each context; (b) the interactional constraints proper to the instructional context; and (c) the difficulty of the task.

As for **referential constraints**, the study 1 context elicits an INSTRUCT-EX that delivers new information to the addressee on how to play the target educational game. In contrast, the study 2 context elicits a PROCESS-EX that focuses on chained events as they appeared in a short sequence from the cartoon previously viewed and narrated by the participant. Considering the **introduction of reference**, referents need to be introduced only in the first context. As a consequence, children should produce more **new information markers** such as "it is", "there is" or "there are" in the INSTRUCT-EX context compared to the PROCESS-EX context. Considering the **reference itself**, distinctive sets of **connectors** should be used in each context. For example, children should use comparatively more logical connectors (e.g.: "in order to", "otherwise", "if... then") in the INSTRUCT-EX context that favour the expression of alternatives and they should use comparatively more chronological connectors (e.g.: "then", "and then") in the PROCESS-EX context that favour the expression of temporality and series of events. Examples 1 and 2 in Appendix 1 illustrate both types of explanations (new information markers are underlined; logical connectors are underlined and in bold characters; chronological connectors are in bold characters).

Interactional constraints should be present in the instructional context as the INSTRUCT-EX must deliver accurate information to the addressee and the instructor child has to make sure his/her partner understands how to play the target educational game. In contrast, the study 2 context elicits a PROCESS-EX with no definite issue apart from answering to the experimenter's prompt that begins the interaction. In the instructional context, it is the child's additional task to monitor the interaction while verbalizing his/her explanation. As a consequence, INSTRUCT-EX should incorporate a specific set of linguistic markings including **phatic expressions** the speaker uses to capture the addressee's attention and check his/her understanding (e.g. "look", "OK?", "got it?"), as well as **modal verbs and expressions** (e.g. "you have to", "you must", "you can") that help introduce the actions the addressee will have to do while playing the game.

We argue that the intrinsic **difficulty of the task** is higher in the instructional context compared to the other context. First, the verbalizing of the PROCESS-EX is made easier by the fact that the child, during the narrative task that preceded, already recounted the chain of events he is supposed to depict to answer the 'how' question from the experimenter. In contrast, the verbalizing of the INSTRUCT-EX requires an original wording of the target game characteristics and the way to play it. Second, there are more pragmatic constraints on the production of the INSTRUCT-EX compared to the production of the PROCESS-EX, above all because of an additional interactional stake in the instructional context. As a consequence, the difficulty of the task should be indexed first by the length of the production, with INSTRUCT-EX having more clauses than PROCESS-EX, and second by the presence of **on-line enunciation-process markers** such as the following (Candéa, 2000; Henry, 2005; Henry & Pallaud, 2004; Martinot, 2000, 2003, 2013):

- Repetition of a word or a syntactic unit (e.g.: "ben on on a un bout de bois" "uhm we we have a piece of wood" – dyad 06, spatiality game);
- Rewording (e.g.: "ben en fait avec le avec la souris ben il faut appuyer sur euh le chiffre" "uhm in fact with the with the mouse you have to press on uhm the number" – dyad 18, number game);
- Filled pause (vowel pronounced at the end of a word or otherwise independently, average time between 15-20 seconds, e.g.: "il va te dire par exemple euh montre moi sept" "he will tell you for example uhm show me seven" – dyad 26, number game);
- Abnormal vocalic lengthening (average time between 18 and 22 seconds, e.g.: "indique-moi:: six billes" "show me:: six marbles" – dyad 16, number game);
- Lexical false start: a word begun and interrupted but which is then completed at the same syntactic spot (e.g.: "et aussi il y avait des euh des t/ des tiers de glace" "and also there were these uhm these l/ these levels of ice" – dyad 15, spatiality game);
- Syntactic false start: incomplete syntactic unit replaced by a different syntactic construction (e.g.: "<et en fait il y a> il te demande un chiffre" "<and in fact there is a> they ask you for a number" – dyad 30, spatiality game).

We expected children to show more enunciation-process markers during INSTRUCT-EX than during PROCESS-EX.

Gesture annotation and coding

Gesture annotation started with identification of the co-speech gesture units (hand gestures, head gestures, shoulder shrugs) performed by each participant during the production of his/her explanation. In order to decide whether a body movement should be counted as a gesture unit, we used a method based on Adam Kendon's proposals (see Colletta, Pellenq & Guidetti, 2010). The coder took the following three criteria into account: movement, location and configuration of the gesture stroke – the gesture stroke is the meaningful part of the gesture phrase, as explained in Kendon, 2004 –, assessing each one on a 2-points scale as presented in Table 1. For a gesture to be counted as a unit it had to score 3 or more points.

Table 1. Gesture identification

Criteria	Scale	Coding
	Noticeable (good amplitude)	2
	Not very noticeable	0
	Between the two	1
	Positioning	2
	In front of the speaker	0
	On the side (less noticeable by addressee) Between the two	1
	Configuration	2
	Corresponds to a precise form	0
	Corresponds to an imprecise form Between the two	1

Each gesture was then attributed a function. Building on previous classifications (McNeill, 1992; Cosnier, 1993; Kendon, 2004) we distinguished between three main categories:

- **referential gestures** (representative and deictic gestures),
- **pragmatic gestures** (discursive, framing, performative and interactive gestures),
- **word searching gestures**.

REFERENTIAL GESTURES help build the reference. This category includes deictic and representational gestures. The deictic gesture is a hand or head movement that points to an object present in the communication setting, or to the interlocutor, or to oneself or a part of the body, or that indicates the direction in which the referent is found from the actual coordinates of the physical setting. The representational gesture is a hand or body movement that represents a concrete object or a property of that object, a place, a trajectory, an action, a character or an attitude, e.g., the two hands forming an oval to represent an egg or a ball or a rapid downward movement of the hand or index finger to represent the fall of an egg or what happens when you strike a ball – these gestures correspond to the “iconic gestures” in McNeill (1992)’s classification –; or else symbolises an abstract idea, through metaphor, e.g., the right hand in a bowl shape, palm facing upward, to symbolize the focus of discourse, a negation head movement to represent the inability or ignorance of a character – these gestures correspond to the “metaphoric gestures” in McNeill (1992)’s classification.

PRAGMATIC GESTURES help express communicative acts, frame the verbal utterance and structure discourse. This category groups performative, interactive, framing and discursive gestures. A **performative gesture** expresses a speech act (yes answer, no answer, reply, etc.) either in replacement of speech, e.g., nodding one’s head in agreement; or which reinforces the illocutionary value of the speech act, e.g. head nodding accompanying an affirmative response –these gestures are part of the “pragmatic gestures” type in Kendon (2004)’s classification. An **interactive gesture** indicates that the speaker requires or wishes to verify his partner’s attention or has reached the end of the speech turn or narrative, e.g., the speaker touches his partner to call on his attention; or indicates to the speaker that his interlocutor is paying attention to his speech, e.g. nodding the head while listening to the speaker. These gestures often occur with changes in gaze patterns and were respectively called “phatic signals” and “feedback signals” in Cosnier (1993)’s gesture classification. A **framing gesture** expresses the narrator’s emotional or mental state while performing a speech act, e.g., shoulder shrug or facial expression that expresses the obviousness of what is being asserted, or using 'finger inverted commas' to express distance in relation to terms used – these gestures are part of the “pragmatic gestures” type in Kendon (2004)’s classification. A **discursive gesture** is a hand or head movement that helps to structure speech and discourse by accentuating or highlighting certain linguistic units, e.g., rhythmic movements (beats) accompanying the accentuation of certain words or syllables – these gestures were named

“batonic gestures” in Ekman & Friesen (1964)’s classification; or marked discourse cohesion by linking clauses or discourse units, e.g. rapid flick of the hand towards the right that accompanies a connective such as 'then' or 'after', anaphoric gesture, e.g. , pointing towards a spot in frontal space which previously represented a referent in order to reactivate the same referent – these gestures correspond to the “cohesive gestures” in McNeill (1992)’s classification.

The third category, WORD SEARCHING GESTURES are hand movements, often accompanied by facial expressions, performed by the speaker when encountering difficulties in verbalizing the message, e.g., tapping fingers whilst searching for words, with or without a reflective expression.

For the purpose of our study, we used gesture variables and gesture rate measures (number of strokes per clause) as an index of:

- the referential and interactional constraints proper to each context;
- the difficulty of the task.

We expected gesture rate to be higher in the instructional context compared to the other context. Unlike PROCESS-EX which is a single goal monologue task, INSTRUCT-EX is a dual-goal dialogue task that involves not only the building of reference, but also the monitoring of the on-going interaction. Each goal should generate gestures – referential gestures for the building of reference, pragmatic gestures for the monitoring of the interaction – with as a consequence more gesture during the dual-goal task.

We expected representational gesture rate to be higher in the PROCESS-EX than in the INSTRUCT-EX, as the focus is almost exclusively on the building of reference. Conversely, we hypothesized pragmatic gesture rate to be higher in instructional explanations than in process explanations, as this latter should generate only small amounts of pragmatic markers, if at all.

Finally, we expected word searching gesture rate to be higher in the INSTRUCT-EX type as it is a dual-goal task involving an original wording (no previous enunciation). Word searching gestures should either appear together with enunciation-process markers, or find their production correlated with these markers.

Reliability

In order to establish reliability in gesture coding, in study 1, once the first coder tagged movements as gestures, she categorized them according to gesture type, in relation to the speech they accompanied. A second coder categorized 26,8% of the gestures (82 gestures out of 305) where these gestures represented both conditions (game explained and visibility) and 6 different dyads. Agreement between coders was 91%, across all gesture types. In study 2 a second coder validated the annotations made by a first coder and settled any disagreements. Inter-rater agreement on the identification of gesture units — also in relation to the speech they accompanied — was 90% and agreement on the function attributed to each stroke was 95%.

3.5 Synthesis of our goals for this study

In the following table, we explicitly link the four hypotheses we established in section 3.2 and the measures described in the previous section.

Table 2: Synthesis of our hypotheses

Hypotheses	Expected measures
H1. Young children aged 6 years show competencies related to a dual-goal finalized dialogue task	More new information markers, logical connectors, and modal structures with addressee's markers in INSTRUCT-EX and more chronological connectors in PROCESS-EX
H2. At this age, a dual-goal dialogue task is more difficult than a single goal monologue task	Longer explanations in INSTRUCT-EX More on-line enunciation process markers in INSTRUCT-EX and more Word searching gesture in INSTRUCT-EX
H3. Pragmatic constraints proper to each task show both in language and gesture	Higher gesture rate in INSTRUCT-EX
H4. Young children adapt their use of gesture resources to accomplish the task	Same referential gesture rate in the two types of tasks and higher pragmatic gesture rate in INSTRUCT-EX

4. Results

The analyses that follow concern linguistic variables (mean number of clauses, mean number of new information markers, of connectors, of modal structures and of enunciation-process markers) and gesture variables (mean number of gestures par explanation, of referential, pragmatic and word searching gestures). We compare the two types of explanations for each variable. As the explanations are very different and have different lengths, we tested the normality and the condition of homoscedasticity between the two datasets (INSTRUCT-EX and PROCESS-EX) for each variable: when the normality and/or Levene test were verified, we ran a parametric test. When these tests were not verified, we ran a non parametric test. For the following variables, we ran a parametric test (test T): mean number of clauses per explanation, mean number of new information markers (according to the number of clauses per text), mean number of connectors (according to the number of clauses per text), mean number of enunciation-process markers (according to the number of clauses per text), mean number of gestures per clause, mean number of referential gesture per clause and mean number of pragmatic gesture. For the following variables, we ran a non parametric test (Mann Whitney test) : mean number of modal structures (according to the number of clauses per text) and mean number of word searching gesture. Concerning phatic expressions and word-searching gestures, we did not have enough data to perform any tests.

4.1 Linguistic analyses

Mean number of clauses per explanation

Figure 1 presents the mean number of clauses per explanation. The test T Student reveals that the Instructional explanations ($\bar{x} = 11,06 / SD = 4,3$) contain significantly more clauses than the Process explanations ($\bar{x} = 5,47 / SD = 4,2$) ($t = 3.584$, $ddl = 28$, $p = 0.001$).

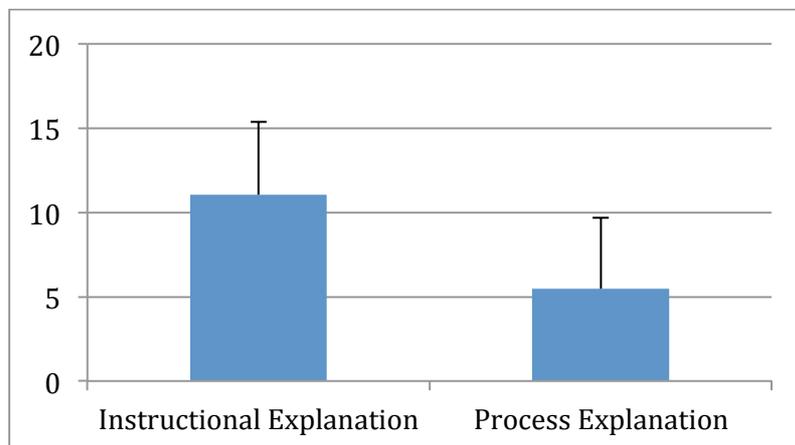


Figure 1. Mean number of clauses per type of explanation

Children produce more clauses during instructional explanation than during process explanation.

Mean number of new information markers

Figure 2 presents the mean number of new information markers per clause. The test T Student reveals that the difference between the mean number of new information markers per clause in the instructional explanations ($\bar{x}=0,21$ / SD = 0,01) and the process explanations ($\bar{x}=0,025$ / SD = 0,007) is significant ($t=4.897$, ddl 28, $p=.000$).

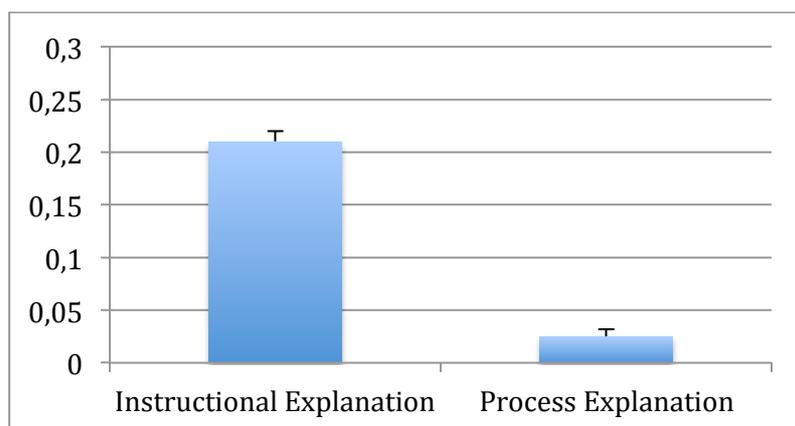


Figure 2. Mean number of new information markers per clause

Children produce more new information markers in the instructional explanation than in the process explanation.

Mean number of connectors

The test T Student reveals the difference of proportion of connectors per clause in the instructional ($\bar{x}=0,92$ / SD = 0,04) and process explanations ($\bar{x}=0,85$ / SD = 0,03) is not significant ($t=0.52$, ddl 28, $p=0.191$).

Qualitative analyses reveal that during instructional explanation, children used comparatively more logical connectors (21%) than chronological connectors (16%), whereas during process explanation, children used comparatively more of the latter (39%) than logical connectors (14%). Together with logical connectors, discourse structure markers such as 'ben' et 'alors' (well), 'en fait' (so), 'voilà' (you see) were produced in higher quantity in instructional explanation (28%) than in process explanation (5%).

To sum up on connectors, the principal difference is the use of structural markers of

conversation and logical markers that characterise instructional explanation.

Mean number of modal structures

Figure 3 presents the mean number of modal structures (verbs, adverbs) per clause. The Mann Whitney test reveals that the difference between the mean number of modal structures per clause in the instructional ($\bar{x} = 0,139$ / $SD = 0,01$) and the process explanations ($\bar{x} = 0,05$ / $SD = 0,01$) is significant ($U=59.50$, $p=.026$).

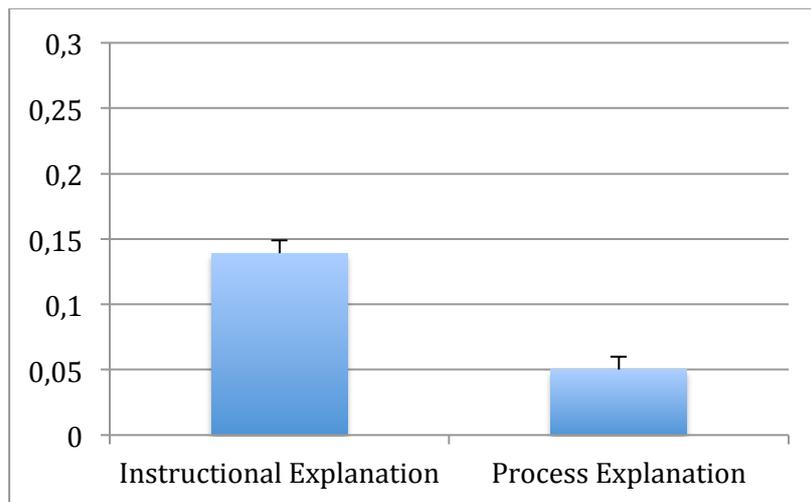


Figure 3. Mean number of modal structures per clause

Children produce more modal structures in the instructional explanation than in the process explanation.

Mean number of enunciation-process markers

Figure 5 presents the mean number of énonciation process markers per clause. The Mann Whitney test reveals that the difference between the mean number of enunciation process markers per clause in the instructional ($\bar{x} = 0,06$ / $SD = 0,05$) and the process explanations ($\bar{x} = 0,33$ / $SD = 0,49$) is significant ($U=181.50$, $p=.003$).

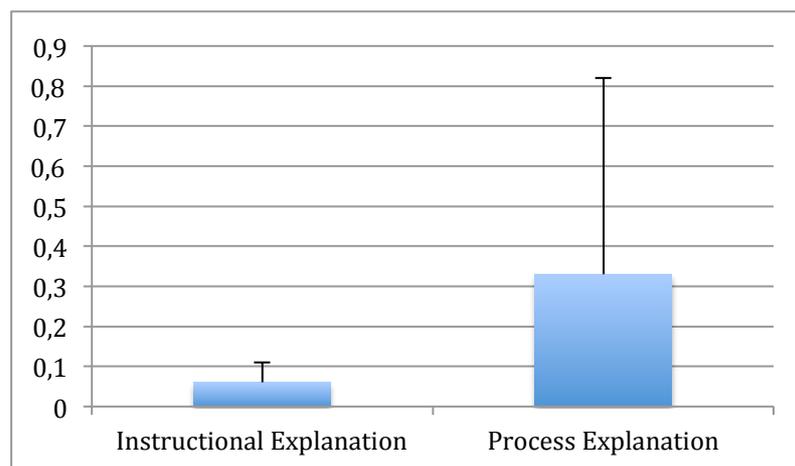


Figure 5. Mean number of enunciation process markers per clause

Children produce more on-line enunciation process markers in the process explanation than in the instructional explanation.

4.2 Gesture analyses

Mean number of gestures per clause

The test T Student reveals the difference of proportion of gestures (all gesture types: referential, pragmatics (discursive, interactive, performative and framing) and word searching) per clause in the instructional ($\bar{x} = 0,58 / SD = 0,5$) and process explanations ($\bar{x} = 0,86 / SD = 0,6$) is not significant ($t = -1,322$, $ddl = 28$, $p = 0,197$).

Referential gestures

Figure 6 presents the mean number of referential gestures per clause. The test T Student reveals the difference of proportion of referential gestures per clause in the instructional ($\bar{x} = 0,26 / SD = 0,3$) and process explanations ($\bar{x} = 0,67 / SD = 0,51$) is significant ($t = -2,514$, $ddl = 28$, $p = 0,018$).

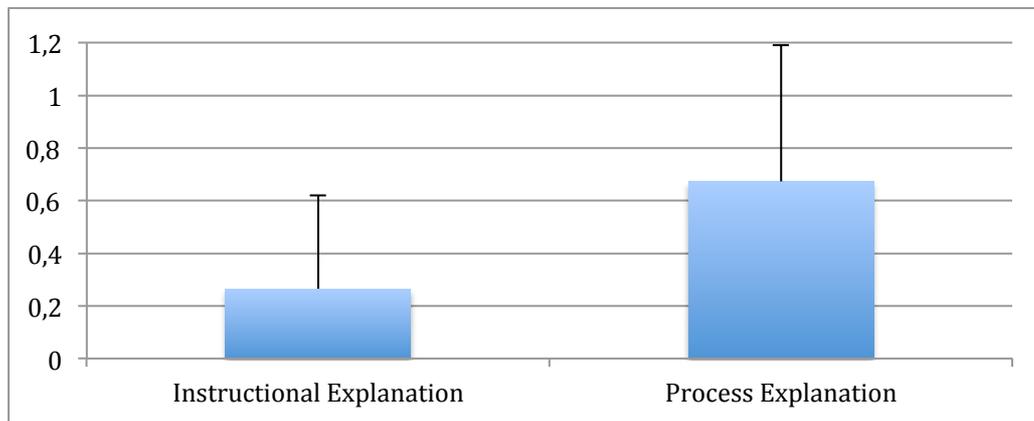


Figure 6. Mean number of referential gesture per clause

Children produce significantly more referential gesture in process explanations than in instructional explanations.

Pragmatic gestures

Figure 7 presents the mean number of pragmatic gesture per clause (for this analysis, we included only discursive and interactive gestures because the rate of performative and framing gestures were too low). The test T Student reveals that the difference in rate of pragmatic gesture per clause in instructional explanations and process explanations is significant ($t = 3,990$, $ddl = 28$, $p = 0,000$).

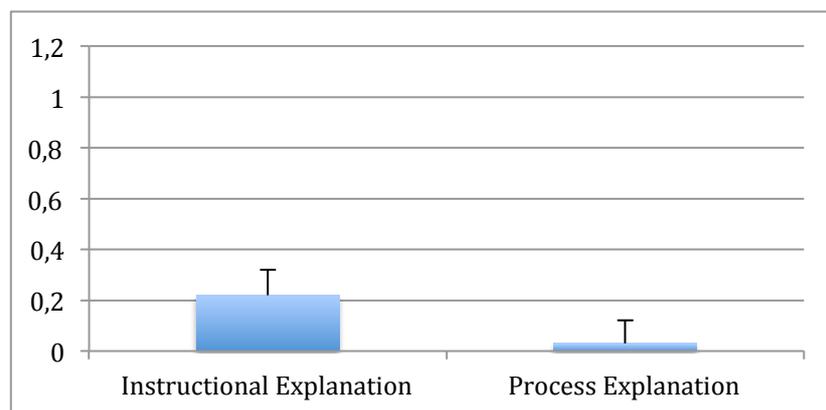


Figure 7. Mean number of pragmatic gesture

Children produce more pragmatic gesture in the instructional explanation ($\bar{x} = 0,22 / SD = 0,1$) than in the process explanation ($\bar{x} = 0,03 / SD = 0,09$).

5. Discussion

Analyses were run to verify our general hypotheses. Table 3 shows each hypothesis, the expected measures associated with it and the results of each measure. Results revealed that the type of explanation (Instructional versus Process) had an effect on several variables measured. Most variables, both linguistic and gestural varied significantly according to the type of the explanation.

Hypotheses	Expected measures	Results
H1. Young children aged 6 years show competencies related to a dual-goal finalized dialogue task	More new information markers, logical connectors, and modal structures with addressee's markers in INSTRUCT-EX and more chronological connectors in PROCESS-EX	Confirmed except for connectors but there are differences in logical connectors
H2. At this age, a dual-goal dialogue task is more difficult than a single goal monologue task	Longer explanations in INSTRUCT-EX More on-line enunciation process markers in INSTRUCT-EX and more Word searching gesture in INSTRUCT-EX	Partly confirmed for linguistic measures Inconclusive for gesture measures (word searching gestures)
H3. Pragmatic constraints proper to each task show both in language and gesture	Higher gesture rate in INSTRUCT-EX	Infirm, although both types of explanation were bimodal
H4. Young children adapt their use of gesture resources to accomplish the task	Same referential gesture rate in the two types of tasks and higher pragmatic gesture rate in INSTRUCT-EX	Infirm for the referential gesture rate, confirmed for the pragmatic gesture rate

Taking the results in order, linguistically, instructional explanation is characterized by a greater rate of new information markers and modal structures, and this partially confirms our hypothesis H1. Firstly, as predicted it makes sense that there is a greater rate of new information markers in the instructional explanations as that content was not previously narrated (whereas the content of the process explanations was already narrated). Secondly, children produce significantly more modal structures in the instructional explanation versus the process explanation. This result can be attributed to the socio-interactional characteristic of instructional explanation. If a speaker knows he is explaining in order to instruct so that an addressee understands enough to be able to carry out the instructed process on his own at a future time, this is clearly an additional constraint as compared to simply recounting a process so that it is understood without further action. That said, we did not have enough phatic expressions to run any comparative tests and perhaps these monitoring skills are what children are developing. In addition, it is not obvious a child feels responsible for the adult understanding what the child narrates in a responsive context with the adult monitoring the interaction. Regarding logical connectors, although we expected that their rate would be higher in Instructional explanation, there were only comparatively more logical connectors (e.g. "in order to", "otherwise", "if... then"). Perhaps then, what really distinguishes explaining an instruction versus explaining a process in terms of connectors is the necessity in the first case to speak about task objectives and consequences of both desired and undesired actions within that task; this is consistent with the idea that explaining as instruction has a social interactional component in addition to a simple referential task. The unexpected difference on the use of discourse structure markers between the two types of explanation, with children using them quite a bit in the instructional explanation (28%) compared to the process explanation (5%), adds consistency to this last view. Continuing our discussion of type of connector that may distinguish our two types of explanation, since chronological

connectors favour the expression of temporality and the relating of series of events, it makes sense that there should be more of them in process explaining (30), as opposed to instructional explaining (24). However, the difference in the raw numbers for our data is not striking. As shown in the data, children who perform the instructional explanation also use chronological connectors to mark the various stages of the game their addressee is about to play next.

Hypothesis H2 was partly confirmed as regards to linguistic measures. Children produce more clauses during instructional explanation than during process explanation. This is an argument in favor of instructional explanation being more difficult than process explanation because there are two tasks (referential and socio-interactional) to manage instead of just one (referential). However, we expected there would be more on-line enunciation process markers in instructional explanation since children doing instructional explanation had to put their explanations into words for the first time whereas children doing process explanation had already spoken about the process in another task. But this was not the case. Rather, we found more of these markers in children doing process explanation. A reason for these unexpected results could be found in the sub-categories of such markers. We made a distinction between 6 types of enunciation process markers that may be grouped into 3 broader categories: - rewording the speech content (with or without any change); - giving oneself some additional time (whether within a filled pause or by lengthening some syllable), - interrupting the speech string (whether on a word or on a longer syntactic unit). Considering their respective proportion, rewordings seem to happen more often during instructional explanation (56%) than during process explanation (39%), while pausal phenomena and interruptions happen more often in process explanation (61%) than in instructional explanation (44%). Children who explain an instruction could be more inclined to do rewording in order to make their explanation more explicit to their addressee, focusing on accuracy rather than on correctness. On the other hand, children who answer a process explanation in response to an adult's prompt may focus more on correctness than on accuracy, which would explain the higher proportion of pauses and interruptions during explanation. These are hypothetical presumptions considering the limited available data. Yet, if they were to be proven correct on a larger set of data, we would have to reconsider the so-called 'difficulty' of discourse tasks in this study as well as on a more general ground. On a related note, in analyses carried out solely on the instructional explanation data (including more explanations than those taken into account for this study), we found that each time a child performed a word-searching gesture, he or she simultaneously verbally used an enunciation process marker, but the reverse was not true (Mazur-Palandre & Lund, 2013). Taken together, these results call for a closer look at the interaction between the types of enunciation markers and their accompanying gestures within different types of discourse.

Let us now consider our results on children's co-verbal gestures. A look at the gesture types gives us results that could be viewed as incompatible with what the on-line enunciation process markers tell us. Notably, if word-searching gestures occur, it is only during instructional explanation. This indicator pleads for a higher difficulty level of instructional explanation as children search more for their words with gestures. Interestingly enough, word-searching gestures may be viewed as the gestural equals to rewordings. Although statistical results come to contradictory results, a more refined view of enunciation process markers with both rewordings and word searching gestures as indexes of search for accuracy leads to results that are more on line with our expectations. As discussed just above, a follow up study should investigate older children and adults performing similar explanation tasks in order to check for developmental issues around enunciation process markers and their accompanying gestures.

Before we look at the results concerning other gesture types, let's take a look at our results on the mean number of gestures per clause according to explanation type (hypothesis H3). We

expected that there would be a higher rate of gestures during instructional explanation due to its dual-goal nature and therefore due to each goal generating gestures (both the building of reference and the monitoring of the on-going interaction). But this was not the case. However, one must consider the following; both types of context generate a similar quantity of gesture production in the children, thus confirming other work on language and gesture production among gesture studies. Why the dual-goal instruction task does not generate more gesture remains an unanswered question in the context of our study. Here again, a follow up study should investigate older children performing similar explanation tasks in order to check for developmental issues.

On the other hand, significantly more referential gestures were produced during process explanation and this was partly contrary to our hypothesis H4. We tentatively considered that since both tasks had a referential component, they would have essentially equivalent numbers of referential gestures. But it would seem that the referential component of process explanations is stronger than the referential component of instructional explanation in this data set in that significantly more referential gestures are produced during process explanation. The difference in the reference itself can potentially explain this result. The instructional explanation situation had a smaller amount of different referents than the process explanation situation. In the former, the same referents are used repeatedly during redundant actions. In the latter, however, there is a succession of different referents that appear chronologically and are linked together causally.

In summary, we have shown that instructional explanation and process explanation show differences in both the linguistic and gestural material child speakers use to carry them out. It thus follows that children are capable of adapting their linguistic and gestural expression to the discourse contexts in which they find themselves. That said, the children giving instructional explanation could improve the monitoring of their addressee (for example with an increased use of phatics) in order to ensure building of a shared understanding.

These results therefore also allow us to reflect upon the possible consequences for teaching. For example, the pragmatic abilities involved in socio-interactional goals of human interaction could be explicitly taught to young children who are developing them. Becoming aware of the fact that an explanation needs to be formulated so that an addressee can understand it and also realizing that one needs to check for an addressee's comprehension are important parts of a child's pragmatic development.

Finally, it also follows that our results have wider implications for the study of pragmatics in general. First, they confirm the relevance of studying multimodal indicators as they reflects speakers' reactions to discourse context and second, given what we know about adults, they confirm the relation between how multimodal language in children develops and how children of different ages may react to different discourse contexts. In future work we will gather data from other age groups in order to track the evolution of these pragmatic abilities.

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APPENDIX I

- (1) Example of an INSTRUCT-EX (// is a clause marker and <> signifies on-line enunciation-process markers):

[alors en fait c'est un jeu // t(u) as une euh balle // t(u) as des briques // et en fait et ben tu cliques sur la souris une fois // et avec un morceau d(e) bois en fait tu fais bouger avec la souris t(u) as un morceau d(e) bois sur l'écran et tu le fais bouger // <et ben en fait l(e) but c'est que ça tombe> en fait *tu dois* essayer qu(e) ça tombe pas euh // <s/> euh dessous // <et> en fait et ben euh le but c'est que tu explodes euh les briques // **et puis après** // et ben **quand** tu as fini // et ben tu as deux zèbres // puis <s/> si t(u) as bien aimé // t(u) as un zèbre bleu // tu cliques sur le zèbre bleu <si t(u) as pas très bien aimé> // si t(u) as pas aimé et ben <tu> (il) y a un zèbre rouge et ben tu cliques sur l(e) zèbre rouge // et t(u) as fini **après**]

Translation: "so in fact it's a game, you have um a ball, you have bricks, and in fact um you click on the mouse once and with a piece of wood in fact you make it move with the mouse, you have a piece of wood on the screen and you make it move and um in fact the goal is that it falls in fact you have to try to make it not fall um um under and in fact um the goal is that you explode the bricks and then after and um when you are done and um you have two zebras and i if you liked to play then you have a blue zebra you click on the blue zebra and if you didn't really like to play if you didn't like it um you there is this red zebra and um you click on the red zebra and you are done after that"

- (2) Example of a PROCESS-EX:

[heum:: pa(r)ce que l'oeuf // à chaque fois il tombait sur quelque chose ça s(e) cassait // **et après** y avait la f:: fleur // heu elle/ s(e) cassait cassait cassait // **et après** elle s'est tordue // et **comme** l'oeuf i(l) s'est retombé sur la feuille // et tellement qu'elle était un peu trop // elle était légère la la porte // elle a poussé **et** c'est arrivé chez la souris]

Translation: "because the egg, every time it fell on something it would break, and then the flower, it broke broke broke, and then it got twisted, and because the egg fell on the flower, it was so, so light the door, it opened then it (the egg) entered the mice place"

Group Emotions: The Social and Cognitive Functions of Emotions in Argumentation

Abstract The learning sciences of today recognize the tri-dimensional nature of learning as involving cognitive, social and emotional phenomena. However, many computer-supported argumentation systems still fail in addressing the socio-emotional aspects of group reasoning, perhaps due to a lack of an integrated theoretical vision of how these three dimensions interrelate to each other. This paper presents a multi-dimensional and multi-level model of the role of emotions in argumentation, inspired from a multidisciplinary literature review and extensive previous empirical work on an international corpus of face-to-face student debates. Bringing together argumentation studies and research on collaborative learning, we employ a linguistic perspective in order to specify the social and cognitive functions of emotions in argumentation. The cognitive function of emotions refers to the cognitive and discursive process of *schematization* (Grize, 1996, 1997). The social function of emotions refers to recognition-oriented behaviors that correspond to engagement into specific types of group talk (e. g. Mercer, 1996). An in depth presentation of two case studies then enables us to refine the relation between social and cognitive functions of emotions. A first case gives arguments for associating low-intensity emotional framing, on the cognitive side, with cumulative talk, on the social side. A second case shows a correlation between high-intensity emotional framing, and disputational talk. We then propose a hypothetical generalization from these two cases, adding an element to the initial model. In conclusion, we discuss how better understanding the relations between cognitive, social and emotional phenomena can inform pedagogical design for CSCL.

Keywords Argumentation * Collaboration * Emotions * Group Cognition

Introduction

In the last twenty years, two major theoretical shifts renewed cognitively oriented research on learning, and questioned argumentation theory. The first consisted of the extension of the concept of cognition from an individual to a collective, socio-cultural perspective, with the emergence of research on ‘group cognition’ (Stahl, 2006), and the pragma-dialectic model in argumentation theory (Eemeren & Grootendorst, 2004). The second is the so-called ‘affective turn’, characterized by the inclusion of the affective dimension of learning, with a view on cognition that does not separate emotions from reason. In argumentation studies, some authors also took this turn, or claim that it is necessary to include emotions in argumentation models (e. g. Gilbert, 2004; Plantin, 2011), although they remain a minority in the community. The book edited by Baker, Järvelä and Andriessen, *Affective Learning Together* (2013) is emblematic of this renewed conception of learning processes as consisting of 3 key components: cognitive changes, social practices and emotional behaviors. However in practice, studies in CSCL focus on only one of these dimensions, or at most try to articulate two of them. Computer-supported argumentation systems, for instance, often take for granted an idealized, monological and unemotional version of Toulmin’s model (1958) to describe

arguments (Scheuer, Loll, Pinkwart, & McLaren, 2010). Of course, such approaches fail in addressing the socio-emotional dimensions of actual group argumentative practices. This may result from the absence of theoretical models of how they interrelate to each other. This paper proposes to contribute to this challenge, the exploration of which has only recently begun, by presenting a model of the social and cognitive functions of group emotions in argumentation. As we aim at encompassing a variety of group reasoning settings, our model is based on the typical face-to-face argumentative interaction, but we believe that it is easily adaptable to the specificities of CSCL or CSCW contexts.

Our perspective is situated at the crossroad of argumentation studies and research on collaborative learning, and mostly inspired by linguistics. However, we are aware that only long-term dialogue between several disciplines can successfully achieve this goal. Insights from social psychology, for instance, would undoubtedly enrich this first model. Still, this contribution aims at offering a theoretical basis of discussion to the interdisciplinary and international community of computer-supported collaborative learning, to foster integration into a coherent, multi-dimensional and multi-level vision of collective reasoning.

Our work on group emotions began with an empirical study of class activities aimed at producing group reasoning. Herein, we propose a model that we believe applicable to a wide range of group reasoning settings, including professional contexts. For a heuristic purpose, we present not only the model itself, but also empirical analyses to show how the model can be applied and potentially adapted to interpret authentic data. First, we present the pedagogical situation and data in depth. A second section then specifies our theoretical model and presents the multi-disciplinary literature that inspired it. The third section of this paper is organized around two case studies that led us to refine the relationship between the social and the cognitive functions of emotions for group reasoning. The first case (4.1) shows that low-intensity emotional framing on the cognitive side tends to be associated with consensual footing and disagreement avoidance on the social side. Case 2 (4.2), on the contrary, establishes a link between high-intensity cognitive emotional framing and social engagement with disputational talk, when a competitive footing and rivalry prevail. These cases generate a global hypothesis interpreted in reference to the initial model (4.3). In conclusion, we discuss the potential and limitations of the final, refined model specifically for CSCL design.

1. Educational context and dataset

We believe that achieving a high transparency about the context in which this model was developed permits others to appraise how our conceptual tools can be applied or adapted to other contexts. Moreover, the two case studies described in section 4 are based on data that were part of the same global corpus. Thus, we first specify the pedagogical situation, and then present the nature of the videotaped data.

1.1 Pedagogical situation: the YouTalk ‘scientific café’ activity

The *YouTalk scientific café*-type activity was co-designed by our research group in collaboration with a non-profit, informal science education organization *Les Petits Débrouillards*, under a grant from the regional government. It consists of an extra-curricular activity held at school, during the school day, and while the students (aged 12-14) are grouped as in an existing class (often a science class), even though the event requires modification of their regular class schedule. The activity is generally justified to the students as providing environmental or citizenship perspectives on other subjects. The event lasts between 1h30 and 2h. A key aspect of *YouTalk* is that elder students¹ (aged 15-16) lead the activity. The spatial organization of the class seeks to reproduce the ‘café’, that is in a large room with chairs arranged around tables with each table defining a working group of 3-5 students. Students are generally allowed to choose where and with whom they are seated. The macro-script of the

café alternates between class discussion, working-group discussion, group vote and individual vote, and the whole activity is based on a multiple choice questionnaire slide show. Some questions, called ‘knowledge questions’ represent stable knowledge for which there is a recognized correct answer. These questions aim at mobilizing certain types of knowledge and providing basic information on the topic. Other questions, called ‘opinion questions’, for which all of the options presented are potentially true, are used to stimulate socio-scientific debate. The general topic was current and future drinking water resource management.

1.2 International corpus of videotaped data allowing multiple-scale analysis

Seventeen *cafés* were videotaped in Mexico, the USA, and France using the same general macro-script. A complex recording setting allowed the researchers to do multiple-scale analysis and to study what was occurring at both individual, small group, and class levels. The data for each café, include: a global view of the classroom and moderators’ activity, a screen capture of the slide show, and local views of 2 to 4 table-groups. Ten cafés were selected for analysis based on criteria of completeness and coherence of the entire event (no technical or logistical issues) and in order to obtain a reasonable volume of commensurable data. Several aspects of students’ argumentation were analyzed: type of collaboration in small group, use of different argumentative resources (knowledge, norms and emotions), and a comparative study of debate framing along the three countries (Polo, 2014). This extensive empirical work led us to develop conceptual tools to characterize emotional and social aspects of students’ discourse in relation to cognitive-focused educational goals, which we now propose to integrate into a global model.

2. Emotions in argumentation: a multidisciplinary literature review

In this second section, we provide a multi-disciplinary literature review on the role of emotions in argumentative interactions, focusing on the aspects that inspired our theoretical model, notably perspectives on emotions coming from argumentation studies and considerations of emotions drawn from the literature on collaborative learning. Table 1 summarizes the key features of these two lines of research. Our model of group emotions in collective reasoning is then introduced.

2.1 Emotions in empirical approaches to argumentation

The institutionalization of argumentation studies as a field, in the end of the 20th century, has been accompanied by the development of a critical stance on emotions, perceived in a normative perspective as fallacious or potentially fallacious (e. g. Hamblin, 1970, Walton, 1992). Nevertheless, a recent approach in argumentation studies, reviving perspectives from Ancient Rhetorics, takes a descriptive perspective on authentic discourse and empirically studies how people use emotions as resources to argue (e.g. Micheli, 2010; Plantin, 2011; Hekmat, Micheli, Rabatel, 2013; Plantin, 2015).

Adapting work from psychology (e. g. Cosnier, 1994) into linguistics, Plantin (2011) proposes diverse indicators for studying emotions more or less explicitly invoked in argumentative discourse. While the critical analysis approach names and denounces fallacious appeals to participants’ emotions, such analysis does not necessarily imply precise labeling. Instead, affects are rather characterized along the axes of valency (whether it is pleasant or unpleasant) and intensity (referring to the strength of the affect) (e. g. Plantin, 2011; Cahour, 2013). Plantin (2011) specified for each axis several ‘emotioning parameters’. On the intensity axis, the emotional distance to the issue is considered (in terms of people concerned, space and time), the degree of control over the situation, agentivity and causality from which the situation is described as resulting. Other parameters contribute to the construction of the

valency axis: life-death continuum, anticipated consequences, analogies and conformity to established norms. Such emotioning parameters are studied in discourse, and might appear more or less explicitly. They can be analyzed by examining the use of a specific emotional lexicon (indignation is necessarily related to the accusation of a responsible agent, for instance, while sadness is not), or in reference to cultural *topoi* (for example, in Western culture, a burial is expected to be sad). As a consequence, this type of analysis does not claim to apprehend people's actual feelings, but rather the emotions that they *express* through discourse about themselves, others, or the topic².

Polo and her colleagues combined Plantin (2011)'s tools with Grize's (1996, 1997) concept of *schematization* to better understand how emotions work as resources to argue, and play a role in the cognitive process of arguing (Polo, Plantin, Lund, Niccolai, 2013). A schematization corresponds to both a cognitivo-linguistic process of characterizing-and-appraising an object, and the resulting product of its representation in discourse. The schematization of a discourse object involves cognitive moves which are visible through linguistic operations, and which cast light on selected aspects of the object, producing a specific representation of it. This representation is not neutral (Grize, 1996, 1997), but argumentatively oriented. The term 'orientation' refers to the work of Anscombres and Ducrot on argumentative value of language itself (Anscombres & Ducrot, 1997), which is here expanded to larger discursive units. Part of this 'argumentativeness' of the schematization of discourse objects relies on its emotional framing (Polo et al., 2013). Any emotional tonality associated to a discourse object, more or less positive, negative, strong, slight, or even neutral, results from active discursive work conveying a specific, argumentatively-oriented vision. This notion of emotional schematization corresponds to one of the cognitive ways emotions can function. According to Lipman, "emotions highlight; they make things stand out; they are sources of *salience*" (2003, p. 129).

In summary, this line of research studies two types of research objects: emotional tonality attached to discourse objects, and emotional feeling attached to an *experiencer* (Plantin, 2015). In the first case, a specific emotional framing is associated to an argumentative claim. In the latter, the discourse signifies someone's feelings.

2.2 Emotions in research about collaborative learning

CSCL, and, more generally, research on collaborative learning, generally accepts that emotions play a role in the socio-cognitive processes related to learning. This literature recognizes two different impacts of emotions on collaborative learning.

On one hand, emotions appear to have a positive impact on learning by fostering socio-cognitive conflict (Roschelle & Teasley, 1995). Such effects have been studied for conceptual or practical change, deepening of the space of debate, or even improvement in knowledge (e.g. Andriessen, Pardijs, Baker, 2013; Baker, Quignard, Lund, van Amelsvoort, 2002; Sins & Karlgren, 2013). On the other hand, some studies show that emotions related to argumentative interactions can be detrimental to group achievement. Facing a socio-cognitive conflict implies disagreeing. This can lead to some tensions as thematizing disagreement corresponds to an undesirable move in ordinary conversation (Traverso, 1999; Pomerantz & Heritage, 1984), which can be difficult to manage³. The cognitive process can be disturbed by these tensions and participants might use relaxation strategies that do not foster argumentation and learning (e. g. Andriessen, Pardijs, Baker, 2013). These results concerning the potential negative impact of emotions led educational researchers and practitioners to claim that there is a need to develop studies and tools for emotion awareness and emotion regulation (e.g. Järvenoja & Järvelä, 2013).

CSCL authors generally apprehend emotions as participants' actual feelings. Nevertheless, they mostly rely on discursive clues to assess group reasoning, identifying the type of collective talk developed among the students or co-workers (e.g. Mercer, 1996; Asterhan, 2013; Michaels, O'Connor, Sohmer, & Resnick, 1992). In this field, two oppositions structure the study of emotions: a focus on individual emotions (shame, motivation, etc.) versus a focus on emotional events occurring at the group level (trust, group efficacy feeling, etc.); and the distinction between timescales (long-term collaborative climate and group history versus local emotional constructs occurring during a specific task).

	Argumentative studies	Collaborative learning
Focus	Fallacious strategies vs argumentative resources	Effects on reasoning Individual level & group level
Method	Discourse analysis	(Mainly) Discourse analysis
Object	Expressed emotions	
	people's feeling	objects' tonality
		Felt emotions long-term local constructs

Table 1. Emotions in research on argumentation studies and collaborative learning: key points.

2.3 Group talk and social recognition-oriented emotions

We would like to point out here that some research in collaborative learning, which studies the quality of student talk in groups, addresses phenomena that can be interpreted in terms of group emotions (without being named as such). We do not have space for an exhaustive literature review here, but we would like to mention a work that we find useful to address the sociocognitive process of collective reasoning, notably Mercer and his colleagues categories of *exploratory*, *cumulative* and *disputational* talk (Fernández, Wegerif, Mercer, Rojas-Drummond, 2002; Mercer, 1996, Mercer & Littleton, 2007; Mercer, Neil, Wegerif, Dawes, 1999; Mercer and Sams 2006; Wegerif, Littleton, Dawes, Mercer, Rowe, 2004; Wegerif & Mercer, 1997).

Exploratory talk, considered of higher educational value, is defined as an efficient and explicit form of collaboration in which 'reasoning is visible in the talk' (Mercer, 1996, p. 363). Thanks to the sharing of evidence and explicit reasoning, this type of talk provides a basis for what Gouran (2004) calls a 'constructive conflict', focused on issues rather than personalities. On the contrary, disputational talk corresponds to little sharing of information and reasoning and 'disagreement and individualized decision making', embodied in 'short exchanges consisting of assertions and counter- assertions' (Mercer, 1996, p. 369). Cumulative talk is also considered of low educational value, even if it is highly collaborative, because it is limited to a discussion in which speakers accumulate ideas uncritically, through 'repetitions, confirmations and elaborations' (Mercer, 1996, p. 369).

In addition to the necessary cognitive ability, a group would engage in exploratory talk only if it corresponds to the perceived socially relevant form of talk, identified on the basis of specific emotions expressed in the interaction. These emotions are associated to how social recognition is ensured in the dialogue. This is strongly related to linguistic politeness. Engaging in argumentation implies changing one's way of seeking face preservation³, and, in particular, a change in the status of disagreement, considered as an undesirable move in ordinary conversation. The students might experience uncertainty about the ongoing politeness rules (ordinary or argumentative). In this context, the expression of recognition-oriented emotions work as clues for the group members to engage in a common type of group talk. When a participant expresses emotions about whether her/his face is well preserved or endangered by a given interactional move, others can adjust their behavior accordingly.

In cumulative talk, the participants seek face preservation through agreement rather than by elaborating on the objects under discussion, and avoid disagreement. In disputational talk, face is strongly attached to the individual's opinions, and criticisms are seen as offenses and lead to counter-attacks. Exploratory talk is precisely characterized by the fact that social recognition does not rely on agreement to individual opinions, but rather on cognitive group achievement through the discussion process (Wegerif & Mercer 1997). Engaging in high-quality group interaction requires the students to adopt a politeness system in which there's no shame in expressing ill-structured ideas or changing one's mind, nor aggressiveness in criticizing others' views, nor sadness at not convincing everybody that one's initial idea was the best. Students rather experience happiness at shifting from individual initial arguments to collective stronger ones, which corresponds to intrinsic motivation (Ryan & Deci 2000). In Lipman's (2003) terms, we can say that exploratory talk requires the students to become 'self-corrective' as a group, self-correctiveness being a key feature of critical thinking.

3. A model of group emotions in collective reasoning

In figure 1, we present a model that articulates these theoretical backgrounds in order to propose a global picture of the role of emotions in the discursive, socio-cognitive process involved in reasoning together. For research purposes, a clear distinction is made between their social (dark boxes) and cognitive (white boxes) functions, but, of course, these are in reality occurring together as part of the same global sociocognitive activity.

An interaction never starts from scratch. Each student or participant comes to the table with his or her own preexisting internal emotional state, which includes a priori feelings about the objects to be discussed, and the subjects to be involved in the task. On the cognitive side, the initial formulation of the issue to be debated by the group also constitutes an a priori framing of the activity, which is not emotionally neutral. When the interaction starts, some aspects of these pre-existing entities are selected and filtered, adopting a discursive form to be shared among the participants. Then, two phenomena, one social, the other cognitive, take place gradually and give birth to two types of emotional discursive entities: the semiotization of participants' feelings and the emotional framing of discourse objects. These two emotional entities are unceasingly recreated during the debate, in real-time, with each participant monitoring his own and others' manifested feelings, and specifying the vision of the problem that he is acquiring through an appropriate emotional schematization. We refer to these two phenomena as the social and the cognitive functions of group emotions.

3.1 Social and cognitive expressions of emotions at the individual level

On the social side, the politeness system and, more specifically, the obligation to preserve one's and others' face (facework) (Goffman, 1974; Brown and Levinson, 1988), constrains which emotions the subjects manifest, if and how they thematize their own and others' feelings. At the individual level, participants manifest and interpret feelings in relation to their choice of adopting a more or less collaborative self-identity footing, which can either be a) *consensual*, and avoid thematizing disagreement to preserve their own and others' faces; b) *constructively critical*, seeking face preservation through group achievement; or c) *competitive* and try to have their own ideas win over others'.

On the cognitive side, participants define and categorize the problem in the course of discussion, insisting on some aspects more than others. This schematization process is partly emotional: the objects, as they emerge in discourse, are given an emotional tonality (Polo et al., 2013). This process orients the discourse toward the defense of an argumentative claim. At the individual level, one decides to argue for one alternative, competing, within the debate,

with one or several other options (here, options A, B, C, D, E or F). To simplify the model, in figure 1, we only represented two options: claim C and claim -C.

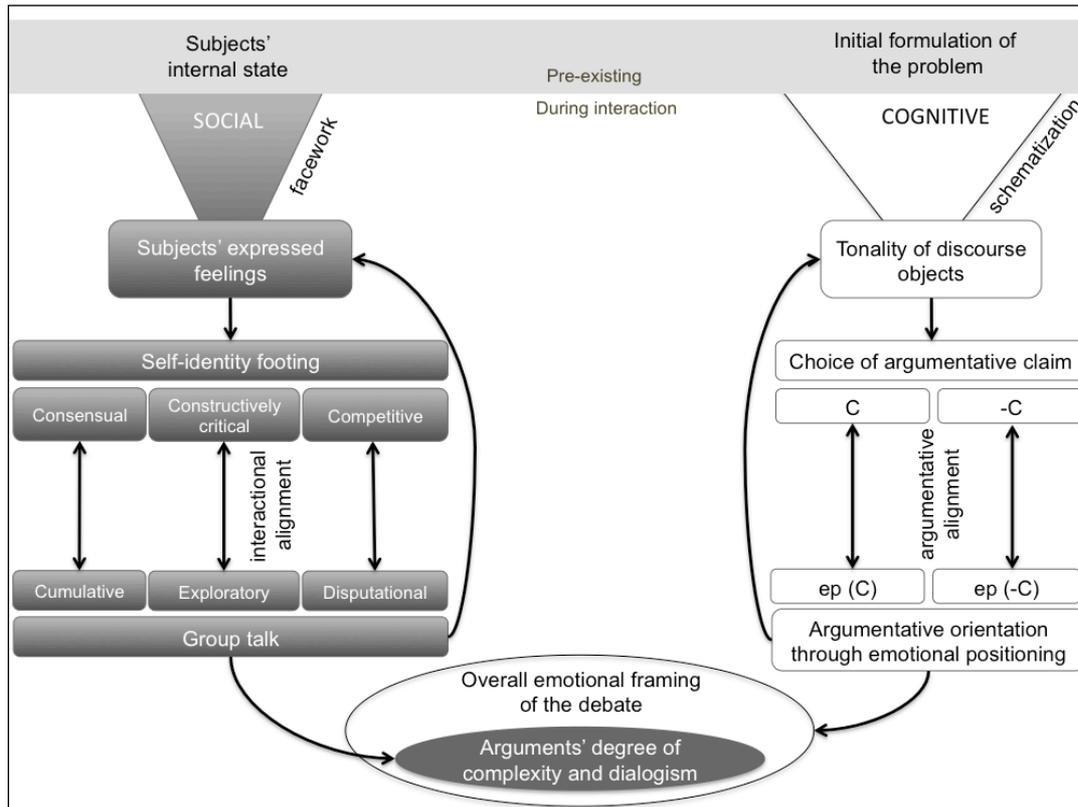


Figure 1. The functions of emotional entities in the sociocognitive activity of reasoning together.

3.2 Sociocognitive alignments and resulting group-level phenomena

In group reasoning, the participants adjust their individual positions (both social and cognitive), through processes of (dis)alignment. Through interactional alignment, the participants become engaged in a specific type of group talk, either disputational, cumulative or exploratory (Fernández, Wegerif, Mercer, Rojas-Drummond, 2002; Mercer, 1996; Mercer & Littleton, 2007; Mercer, Wegerif, Dawes, 1999, Mercer and Sams, 2006, Wegerif, Littleton, Dawes, Mercer, Rowe, 2004; Wegerif & Mercer, 1997). When each member of the table-group is aligned on a consensual footing, the group talk is cumulative; when they are aligned on a constructively critical footing, the group talk is exploratory; and when they are aligned on a competitive footing, the group talk is disputational. Exploratory talk is characterized by the fact that social recognition relies on cognitive group achievement. In cumulative talk, the discussion of the issue is restricted to a non-controversial process, the participants seeking face preservation through consensus. On the contrary, in disputational talk there is strong disagreement but little collective reasoning. Face is then strongly attached to the individual's opinions, and criticisms are seen as offenses and lead to counter-attacks.

Through argumentative alignment, the persons defending the same argumentative claim develop a similar emotional position toward the issue. An emotional position associated to the defense of claim C emerges in discourse, $ep(C)$. Its counterpart, for people defending the rival option -C, is the emotional position $ep(-C)$. Here, the collective configuration does not refer to the material group, but to an *ad hoc* entity based on intellectual affinity. It might group students together that are sitting at different tables. Sides arise in the whole classroom, during the debate, opposing students with different argumentative claims and associated emotional

positions. Each time a participant contributes to the debate in favor of option C (or $-C$), his discourse will be argumentatively oriented toward C, through an emotional phasic move toward $ep(C)$ (or $ep(-C)$). Here the adjective ‘phasic’ is employed in opposition to the ‘thymic’ emotion: the latter corresponds to the initial affective state, disturbed by the emergence of, phasic emotional variations (Plantin, 2011). In the psychological tradition, the thymic mood refers to the ‘normal state of composure’ that a subject experience before the occurrence of an emotional episode, which in turn is referred to as a ‘phasic’ move, characterized by a raise in affective feeling (e. g. Cosnier, 1994; Wierzbicka, 1995). Once the emotional episode is over, a subject’s emotional state gradually turns back to his initial thymic level, more or less quickly, depending on the intensity of the phasic emotion. In this model, as in previous work on the role of emotions in argumentation (Polo et al., 2013), we adapted these categories to qualify the debate itself rather than an individual affective experience. Methodologically, this allows one to distinguish between the global tonality of the debate, which serves as a reference for all the participants, and is called the thymic framing; and the local moves in discourse corresponding to the use of emotional schematization strategies to defend a given option, which are referred to as ‘phasic’ variations.

3.3 Debate outcomes at the class level

In terms of outcomes, the sum of the phasic emotional moves resulting from turn-taking between people defending competing options, on the cognitive plane, gives an overall emotional framing to the debate. A resulting thymic tonality emerges, which can be different from the preexisting emotional framing due to the formulation of the problem. On the social plane, the type of group talk impacts the quality of the arguments used, in terms of complexity and dialogism. When exploratory talk occurs, for instance, the students are able to render their initial ideas more complex by integrating others’ counter-arguments, and they finally deliver stronger arguments. This reflects a deepening of reasoning. Independently of who voiced the initial idea or its critical assessment during the group discussion, the final argument made by an individual is strengthened by previous group talk. This can be described in terms of *rebuttals* in reference to Toulmin’s pattern of an argument (1958).

4. Relations between social and cognitive functions of group emotions

This section presents two case studies elaborated with reference to this model, which in turn generate hypotheses about how the relationship between the social and the cognitive functions of group emotions can be specified. More specifically, these cases constitute an argument for suggesting that the nature of group talk is related to the overall thymic framing of the debate. The first one presents a correlation between cumulative talk and low-intensity thymic framing, and the second shows a correlation between disputational talk and high-intensity thymic framing. In a third subsection, we provide a theoretical interpretation of these relationships by proposing a “zooming in” complement to the model presented in the introduction.

4.1 Case 1: correlation between cumulative talk and low-intensity thymic framing

In the available data, cumulative talk was correlated with low-intensity emotional framing of the issue. In small groups, the students do not necessarily focus on the goals set by the exercise: “*while working in classroom groups, children use talk to do much more than engage in curriculum tasks: they form relationships, develop social identities, and pursue ‘off-task’ activities which may be more important to them than the tasks in which they officially engaged – and, as Wegerif (2005) has argued, may be essential to the process of establishing good relationships so that effective ‘on-task’ activities result*” (Mercer & Sams, 2006, p. 517). A clear case shows that they are little centered on the objects of debate as the

thymic emotional tonality is low. The group of Louise, Pamela, Sabrina and Kelly, in the US school, illustrates this correlation.

During the first opinion question, the four girls clearly engage in cumulative talk, but, later in the café, while debating the third opinion question, they turn to emblematic exploratory talk. The two complete dialogues are provided in the appendix. To conduct a linguistic analysis of group talk, we operationalized it into a set of 5 indicators, which are all positive when the girls debate on OQ3. We do not have space here to detail all the analysis of this episode as being exploratory, but we provide an instance of compliance with each one of these indicators to show how our methodology is concretely applied with clear discursive markers.

1) Are assertions and refutations are justified? We then search for segments of discourse such as the highlighted part of the following utterance (turn 1):

LOU er: i think it should be priced by its quality because if [you'd have better quality it's just more work to like produce it]

2) Do the participants elaborate on the argumentative content of previous turns? Such topical alignment are sometimes embedded in gestural or verbal repetitions, as in the following example with Kelly's rephrasing of 'work to produce' into 'production', adding a referential gesture, which Louise repeats at turn 4:

1. LOU er: i think it should be priced by its quality because if [you'd have better quality it's just more work to like produce it]
2. KEL [((nodding head in the affirmative, looking at Louise))
3. KEL em: there's more [production <((turning hands)) for it to>
4. LOU [((turning hands))

3) Do they critically evaluate each other's arguments? Studying this indicator usually implies large sets of dialogues. We here only reproduce two opposed turns of the conversation:

8. SAB and what about (.) family income/ you need water (...)
12. LOU they could like they could overu:se like they could (.) not pay as much and <((turning hands)) get more water>

After a collective elaboration of Sabrina's proposition, at turn 8, to have the price of water depend on family income (turns 9-11), Louise, at turn 12, expresses a concern for a potential undesirable effect of this proposition. She is then taking a critical stance on Sabrina's claim.

4) Is everybody taken into account when making a collective decision? In our data, the students have to come to a common group answer on each opinion question, which is then displayed in front of the whole class. Still, we believe that, even in other settings, this indicator is useful as long as the discussion aims at making an explicit choice. It is essential to understand that concern to have all the group members' consent for the decision does not necessarily imply that the group reaches a consensus. Here, the students solve the problem by selecting on option but ensuring that the other option that some group members got interested in would also be expressed during the class debate:

41. PAM just put C and i'll explain like why we think D too\
42. KEL yeah:\
43. SAB <((putting card C)) well i'm putting C\>
44. LOU C\

5) Do the individual contributions gradually integrate the rest of the group's supporting or opposing argumentation? Or rather, do they only voice the speaker's own initial ideas? The pedagogical situation studied allows us to easily track this type of elaboration, thanks to the alternation of discussion between the group and the class level. Here, Pamela actually

rephrases the different viewpoints developed earlier in the group, when she takes part to the debate at the class level:

<p>PAM oh yeah C and D because em: like we chose C because em: like (0.9) <((opening hands, turned to the sky)) oh i can't really explain> <((hands back to the table)) but like (0.5) however like like however like much time it's putting like (0.3) prod- like producing the water/ should be like (1.0) sold at a higher price like if it's like more better quality it should be sold at a higher price but if it's just (0.5) <((skeptical face)) regular water [i guess> like it should just be (0.7) like affordable\ and then we (0.2) thought D too because em: we thought that like less fortunate families shouldn't be like (0.5) punished not really punished but shouldn't like (.) have like a: <((moving hands)) lack of water> because (.) of like their jobs or whatever their income</p>
--

These indicators also make it possible to specify sequences of talk which are not exploratory. Cumulative talk, especially, is characterized by very low critical sense (indicator 3), as if the discursive and interactive exploration was restricted to the uncontroversial side of the issue. This is the case when the girls discuss about OQ1. They then all agree that the most promising source of water for the future is economizing water currently available through a more careful exploitation of existing resources. They stick to uncontroversial discourse objects, by collectively elaborating a list of environmentally friendly practices, more or less related to the question. Here, the issue does not seem important enough to them to thematize disagreement and argue about it. They rather turn to the usual environmental education doxa, which they all agree to and feel familiar with, without applying any criteria to distinguish between more or less relevant examples. For instance, when Kelly mentions the chemicals polluting the grass at washing one's car (turn 31), nobody questions how this point relates to the topic.

Coming back to our issue of examining the relations between the social and cognitive functions of emotions in group argumentation, a striking result is also that these two dialogues strongly differ in terms of thymic emotional framing and display of signs of (dis)engagement. In the cumulative discussion about OQ1, the 'cold' framing of the issue allows the girls to formally deal with the task in a very scholarly way, but with minimal effort and personal engagement. On the contrary, the whole group is more engaged in debate about OQ3, which shows higher thymic tonality. More specifically, in their discourse about OQ1, a key emotional parameter, the distance to the people concerned, contributes to the development of a low thymic intensity. Throughout the discussion, the girls discursively present the problem as quite far away from them. They rarely involve themselves into the discussion, and mainly use the third person (turns 7,9, 14, 19, 25), talking about the 'people' who waste water (turn 5). They only use the second person 'you' twice, in a general meaning (turns 19 and 26). The inclusive pronoun 'we' (first person plural) is only used during the following class debate, to report their previous discussion, still with a general meaning. The pronoun 'they' only appears, in their discourse, as members of a collective entity who wastes water, and who should provide some effort in order to avoid wasting too much, but the girls never present themselves as potential victims affected by a lack of water. This parameter is very different when the girls debate about the third opinion question. The distance to the issue is much shorter, producing a much more intense, or 'warmer' thymic framing of the discussion. The girls present the problem of determining the price of drinking water as a matter that they are directly concerned with, as much as anybody ('*all people*', turn 14 ; '*everyone*', turn 18). The two general formulations are made using the second person, more engaging than the third person (turns 1 and 8). A great part of the debate is about whether or not every one should, including poor people, have access to drinking water. At this point, Louise is the only one using the third person, which is consistent with her opposition to the proposition that the price of water should depend on family income. This precise phasic increase of the distance to the people concerned is clearly an argumentative strategy. On the contrary, when Louise suggests considering family income, at turn 8, Sabrina sticks to the use of the second person: '*you need water*'. In doing so, she does not present the financial accessibility as 'other people's problem', but frames it as a global concern involving everybody, including her. Sabrina's

utterance also tends to ‘warm the debate up’ by referring to the idea of necessity. It is not only a matter of moral positioning or ecological principle, but also a concrete problem of material survival, tending to the extreme ‘death’ pole, on the valency side (a consequence schematized as very unpleasant). Similarly, aligned with Sabrina’s phasic increase, Pamela, at turn 9, presents the risk of lacking water in a radical version, as not having water at all (*‘not get water’*).

Moreover, when they discuss the first opinion question, the students display signs of disengagement, which are absent in the exploratory debate about the third opinion question. During the cumulative discussion, they produce several long pauses, check the time, stretch, yawn (turns 35, 36, 37, 41). Therefore, one could be tempted to conclude that the emotional distance to the issue, discursively created on the cognitive side, mirrors the students’ actual emotional degree of engagement. Nevertheless, these data do not provide us with any insight about the students’ real emotional state, but only the image of this state as manifested by the students in their discourse and behavior. Moreover, in psychology, there is still a debate about whether or not an internal emotional state can be disconnected from its external expression, and, if so, about the direction of causality between the two⁴. Our interpretation is rather that the emotional schematization of the problem contributes to the argumentative orientation of the debate and structures potential interactional behaviors in a way that constrains expression of (dis)engagement. One cannot easily start yawning in front of someone who is talking about a matter of life or death, no matter how little one may *sincerely* feel concerned about the topic.

4.2 Case 2: correlation between disputational talk and high thymic framing

A clear case of disputational talk was found in the French sub-corpus. A group consisting of four girls, Klara, Samira, Isabelle and Asa starts disputing during OQ 2, and engage in disputational talk again during OQ 3. Still, they manage to soften the conflict and organize a de-escalation during the rest of the café, avoiding another typical dispute during the last group debate on the main question. To do so, they mainly use a disengagement strategy. Even when confronted with a real sociocognitive conflict, the students solve associated tensions by social-only relaxation rather than sociocognitive strategies. This is consistent with previous work showing that group effective collaboration needs an optimal alternation of tension and relaxation phases (e.g. Baker, Andriessen, Lund, 2009). Actually, it seems that the four friends fail in managing a high-intensity emotional framing at the cognitive level by engagement in exploratory talk, and ‘solve’ the conflict by avoiding the issue, and backing away from the exercise, at the meta-discursive level.

In reference to the above mentioned indicators used to operationalize the analysis of group talk, disputational talk is characterized by a rather negative indicator 1 (repetitions instead of justifications), intermediate indicator 2 (topical alignment), strong but unconstructive use of critical sense (indicator 3) and negative indicator 4 (decision-making practice seeking collective consent) and 5 (actual sharing or ideas into more complex, dialogical arguments collectively owned). We here provide a few examples taken from the discussion of the four French girls on OQ2. The students repeat propositions and counter-propositions (2), without elaborating on the reasons for choosing or rejecting an option, which is necessary for constructive discussion (3), as in the following excerpt:

8	KLA	pff moi j'dis F\ (pff I say F\)
9	ISA	pas F quand même\ (not F\)
10	KLA	mais moi j'fais pas l'C hein\ (I do not do the C ok\)
	(...)	
13	KLA	moi c'est F hein\ (I am F\)

14	ISA	moi j'mets la E hein\ (I put E\)
15	KLA	oh non moi j'fais F\ (ah no I do F\)

When it comes to making the final decision, no discursive work is undertaken to get everybody's consent (4). Instead, without previously asking the others, Samira individually decides to put letter F on the stand, at turn 20, and tell them :

SAM	bon j'ai mis F hein démerdez-vous\ (so i put F, just deal with it\).
-----	--

Klara, who agrees with Samira, is aligned with her attitude and displays overt disinterest in what the two other girls think, since her decision is already taken. This is embedded in turns 33 and 34:

33	KLA	nan mais ça <((geste de la main désignant Samira et Klara)) c'est notre avis à nous deux> <((geste de la main vers les 2 autres)) vous euh mettez c'que vous voulez> (no but this <((pointing gesture at herself and Klara)) is the opinion of the two of us> <((pointing at the others)) you er put whatever you want>
34	SAM	((remet la F)) ((puts F on the stand again))

Much later, at the end of the debate, when the moderator actually asks the students to put their chosen letter up, there is still no seeking for collective consent, but very conflicting gestures. Samira starts the de-escalation strategy by disengaging herself and holding a letter corresponding to Isabelle and Asa's choice, even if she does not agree, just to get rid of the debate. See what happens then:

171	KLA	<((prenant le carton de la main de Samira et le donnant à Isabelle)) nan c'est pas toi qui l'soulèves toi t'es pas E c'est vous qui l'soulevez> <((taking the card from Samira's hand and giving it to Isabelle)) no YOU don't hold it up you're not E YOU hold it up>
172	SAM	<((en levant le F)) nous on est F\ [klara nous on est F\ ([<((pulling lette F up)) we are F\ [klara we are F\
173	ISA	[<((en cherchant à baisser la main de Samira)) nan: mets-en pas deux> (<((putting Samira's hand down)) no: don't put two>

Finally, during the following class debate, this group only contributes twice on the basis of what was earlier said during the group discussion, each time with a student rephrasing her own initial idea, not enriched by a consideration of counter-arguments. When they do so, the other students are simultaneous criticizing what is being said, with a low voice at the group level displaying no collective sharing and ownership of arguments. When Samira contributes to the class discussion, Asa even whispers to her:

ASA	°tu mets pas ma bouche dedans° (°don't put my mouth in that°)
-----	---

This disputational talk was correlated, both in OQ2 and OQ3, with a very high thymic tonality. A complete inventory of students' utterances concerning three parameters of emotional intensity is available in appendix B: people concerned, responsible agents, and spatio-temporal distance. At first sight, there is a contradiction between the way students present the people concerned, and their spatio-temporal framing of the topic.

Spatio-temporally, the issue is presented as fairly far away from the students. The main places mentioned as affected by the water issue are Russia, different parts of Africa, and places characterized by a dry climate, which is not the case in the area where the students live. The mention of Dakar is special in this perspective, since it is related to Asa's family. Even if the place is geographically distant from where the discussion is taking place, to Asa, it may be nearer in terms of emotional distance due to the fact that it is where her grandparents live (a fact explicitly referred to). Still, on the temporal dimension, the students also build significant distance from the issue. In other words, the time when the situation would become threatening is presented as belonging to the future. Nevertheless, some variations appear: it is sometimes a near future, so close that the students themselves can imagine 'the consequences' of their current 'acts' will occur during their life; others represent the consequences further in the future more likely to affect the next generations, for example their 'grandchildren'. An

interesting feature of the temporal distance construction is that the current time is only explicitly mentioned as the moment when the acts causing the water issue are committed.

When it comes to directly depicting the people concerned by the problem of access to water, the global picture is rather different, consisting of a high emotional proximity. Out of 41 utterances inventoried, 13 correspond to a first person footing, either in singular or plural form (French *je, j', nous, on*), and 14 to the second person, mostly singular (*t', toi, tu*), with also one plural form (*vous*). Even when the third person is employed in this sequence, it often refers to close proximity to the issue. Two occurrences of *ils* (third person plural) in fact stand for the further employed *vous* (second person plural), corresponding to the present students who went to Russia on a scholar trip. The remaining four occurrences of the third person concern other close relationships: students' future children (twice) or grandchildren, or Asa's grandparents. Only 6 utterances use the third person (*ils, autres*) to refer to distant others. In terms of valency, the problem is only presented as radical and potentially leading to death in two occurrences, corresponding to distant others in danger of not having water at all ('they don't have water', 'they don't have anything'). In the rest of the utterances, the people concerned, mostly the students themselves and their family, are characterized as water consumers facing the matter of how much they have to pay for water, and how much water they can use for their daily needs and their personal comfort. Lastly, Samira makes an original contribution to the group debate on OQ3 as she extends the issue as concerning humanity as a whole: '*on est tous égaux et au fond on est tous des humains\ on a tous les mêmes droits*' (we are all equal and in the end we are all humans\ we all have the same rights\).

The contrast between the two parameters of spatio-temporal framing and people concerned show that the distance to the issue is not only determined by the objective external material conditions (the local situation with respect to water), but is truly discursively built. The students here, even if they are aware of not belonging to the most endangered population in respect to water access, do extensive work to take the issue seriously, both as a concern for all of humanity and as their own local problem.

Lastly, the four girls spend significant time elaborating who is responsible for the evolution of the situation regarding the water issue. In total, 90 occurrences of linguistic markers qualify those taken for responsible (pronouns, names, etc). A structuring feature is the identification of the students with the agents responsible for a change leading to a better situation. This identification is made directly, by an extensive use of the first person singular (*je, j', moi*), in 17 occurrences, and expression with a value of first person plural (*on, nous*), in 15 occurrences. The identification also relies heavily on the use of the second person singular, with the students directly accusing each other of being responsible for the situation. We counted 17 occurrences of *tu* or *t'* and verbal forms in second person singular, and 5 occurrences of direct citation of some students' names (Samira and Klara). It is interesting to note that the alternation of first and second person has been proved as an effective empirically defining characteristic of the conflict genre (Denis, Quignard, Fréard, Détienne, Baker, Barcellini, 2012), which is consistent with the fact that the students here are engaged in disputational talk.

The rest of the linguistic markers depicting the people responsible for the situation all use the third person, and present a variety of meanings. Fifteen occurrences of various forms of "he", "she", or "they" refer to the group of precursors who will initiate a change in their practices that would end up making a difference. There is a debate between the students on how many people are needed to actually have a meaningful impact, and whether or not it's worth getting personally involved in this cause. As a result, the third person here sometimes stands for a first person plural value, when the students perceive themselves as belonging to this group of precursors. Isabelle's utterance, during a side-discussion on opinion question 2, is emblematic

of this figure: *'si on est trois millions ça changera'* (if there are three million of us, that will make a difference). A second group of third person utterances corresponds to a general entity that does not explicitly include the students, but from which they cannot totally stand apart: 'people'. This global, poorly determined, agent is characterized by reluctance to change habits, egocentrism and laziness, and is defined as the majority of society's members. A total of 14 occurrences refer to this entity. Several of these occurrences are embodied by the word *personne* (nobody), a radical form that also semantically includes the students themselves. A third instance of third person use consists of the people defined as the most responsible for the situation, their higher culpability due to the fact that they actually take advantage of the problematic situation (4 occurrences). Here, there is usually no identification with the students, as it mostly concerns industries making money out of the situation. Surprisingly, one isolated occurrence of the *on* (we) presents similar features, during class debate on opinion question 3: *'on la vend un peu plus cher'* (we sell it at somewhat higher price). This can be understood as a feeling of collective culpability for the general organization of the society they belong to, a society that makes possible this kind of profit⁵.

It is interesting to note that two of these occurrences of the third person can be considered as depicting both people concerned and responsible agents. The first one refers to children's 'parents', whose lifestyle is related to the water issue, both as a cause of the environment problem and as a way in which this problem can affect them (here, they might have to clean dry toilets). The other occurrence with this double status is a third person plural ('ils', *they*) referring to the people lacking water because they might not pay for it. This sentence is ambiguous and does not enable us to decide whether such people are considered as social victims for not affording to buy water or whether they are presented as responsible for their problem, which would be to say that it's their fault is they cannot even pay for water.

All things considered, one can say that the emotional thymic tonality of the debate among the four students is very high along the intensity axis. A specificity of this case is that the proximity to the issue does not only rely on the identification with the people concerned but also, indeed mostly, with the people responsible for the evolution of the situation. Such framing implies auto and hetero accusations and culpability, favoring a feeling of being offended and needing to defend one's self. This is consistent with the emotional characteristics of disputational talk along the social dimension of argumentation.

Lastly, an interesting aspect of this dialogue is that the students produce a lot of meta-discursive commentaries on the activity they are engaged in. These commentaries are rather negative, and show that their argumentative norms associate debate with the polemical genre. Below we reproduce all of the students' utterances⁶ describing their ongoing activity, during the group debate on the second opinion question, where they must hold up the letter A, B, C, D, E or F corresponding to their group choice⁷:

ISA	bah oui mais l'truc c'est [qu'on doit voter pour l'groupe\ (yeah but the thing is [that we must vote for the group\ (...)
ASA	[ah: tu m'affiches pas avec ça hein\ ([ah: don't shame me by associating me okay\ (...)
ISA	<((en riant)) toi tu cherches pas l'embrouille> <((laughing)) you are not provoking the conflict> (...)
SAM	<((riant)) nous on n'est pas d'accord klara\> [on va <((pose le poing sur la table)) débattre\> <((laughing)) we do not agree klara\> [we're gonna <((poses her fist on the table)) debate\> (...)
KLA	<((prenant le carton de la main de Samira et le donnant à isa)) nan c'est pas toi qui l'soulevés toi t'es pas E c'est vous qui l'soulevez> <((taking letter E from Samira's hand and giving it to isa)) no it's not you who must hold it up you're not E you must [hold it up> (...)
ISA	°<((riant, à ASA)) ça sent la guerre>° (°<((laughing, to ASA)) this smells like war>°)

Both lexicon and gestures refer to the semantic field of conflict and war. The analogy used to characterize the interaction is the one of a battle. While the moderator is announcing the next

group debate, about OQ3, Samira expresses anxiety about the coming phase, anticipating the conflict:

SAM °on va s'taper là° (°we are going to start fighting again°)

Similar negative metadiscursive comments at the table on the nature of the ongoing activity continue during the discussion on OQ3:

SAM bon maint'nant on fait pas d'merde hein\ (so now let's not just do shit okay\) (...)
 ASA ((entoure sa tête de ses mains simulant une grosse tête)) (puts her hands around her head to simulate a big head) (...)
 SAM isa tu défends ta cause\ (isa you defend your cause\) (...)
 SAM on est en train d's'entretuer\ (we are killing each other\) (...)
 ISA c'était d'la merde\ (that was shit\) (...)
 SAM tout l'monde se dispute\ (everybody is arguing\) (...)
 ASA mais c'est bon arrêtez avec vot' débat on va pas parler\ (but it's enough stop with your debate we're not gonna talk\) (...)
 ISA t'arrêtes de t'exciter toi un peu là/ (you stop getting so annoyed, will you/)

This representation of the activity contributes to the shift from strong individually opposed convictions on the issue to interpersonal conflict. The debate is mainly described in terms of its (potential) detrimental effects on participants' relationships. Therefore, the activity is mostly thematized through its social implications, and very little is said at the metadiscursive level about the matter of conciliating or co-elaborating the alternative views on the topic.

The girls finally turn to a cognitive disengagement strategy, which strengthens the group by reactivating a common role of 'poor student' that they seem familiar with. The negative stigma is explicitly mentioned and used as a shared identity feature for the (re)construction of group unity. During the class debate on OQ2, the students produce a self-devaluating discourse that correlates with strengthening the feeling of belonging to the same group:

1 ISA <((en regardant l'enseignante)) madame dupont> (<((looking at the teacher)) mrs dupont>)
 2 KLA eh elle va s'dire elle aura honte de notre classe\ (she's gonna think she's gonna be ashamed of our class\)
 3 KLA aussi ils ont pris la pire classe comme ça euh ils ont pris les pires gens d'la classe 'fin\ (also they took the worst class and then em they took the worst people in the class in fact\)

4.3 Articulation of social and cognitive functions of group emotions: generalization

The two case studies presented in the previous sections show a correlation between the thymic framing of a debate and the tendency to engage in distinct types of talk at the group level (disputational, exploratory, cumulative). In figure 2, we propose a representation of such correlations in reference to the model presented in figure 1, zooming in to the bottom part of it, focusing on the collective configurations structured by emotions on the cognitive and the social dimensions, and on their relations to the outcomes of the global argumentation. The model here serves as a basis for conceptualizing, at a theoretical level, the hypotheses generated by these case studies about the relations between group talk and thymic framing. If future studies confirm these hypotheses, such refinement of the model would offer a more complex symbolization of how social and cognitive functions of group emotions are intertwined.

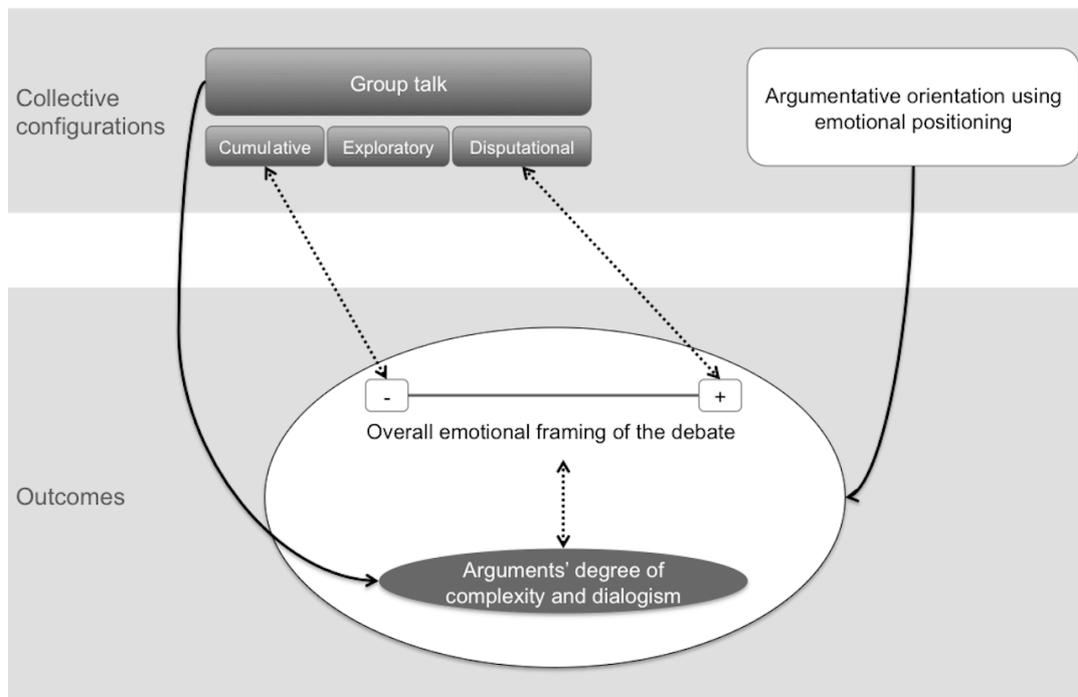


Figure 2. Relation between the cognitive and social functions of group emotions in argumentation: complexification of the model.

Group talk and the thymic overall emotional framing of the debate seem strongly linked. Our interpretation is not a one-way causal link, but rather a cycle of feedback. For instance, specific emotions that play a social function, such as feeling offended, may impact the emotional framing by influencing the participants to feel more or less concerned by, or responsible for, the issue at stake. Similarly, the construction of the distance to the issue, a key component of the cognitive functions of emotions, is likely to produce more or less intense feelings on the part of students depending on how consistent the problem appears to them. Theoretically, we represent this relationship as a continuum. In emblematic cases as those reported above, typical cumulative talk is associated with a low-intensity emotional framing and typical disputational talk corresponds to a high-intensity emotional framing. Still, many authentic interactional phases cannot be easily classified on the whole as belonging to one type of group talk (Polo, 2014, 199-238), and they may admit different sequences also in terms of overall thymic tonalities. Therefore, we have no reason to theoretically exclude any potential intermediate situation between those two poles.

In terms of educational concerns, this dynamic complement to the model has the advantage of highlighting that pedagogical tools and strategies aiming at fostering exploratory talk should address the matter of the optimal general emotional framing of the activity.

Main conclusions and discussion

In this final section, we first summarize the key conclusions of this article, and discuss the significance of our model for the theorization of group emotions, especially its implications for educational design. We then give directions for future work to build upon the present contribution.

Theoretical significance of the model and main conclusions

Distinguishing between social, motivational, affective, and cognitive dimensions of interactions aimed at reasoning together is not an easy task. For analytical purposes, we find it useful to differentiate in a dynamic model (2), the social and cognitive functions of group

emotions, even if they are actually interrelated into a global sociocognitive and affective process. On the social side, group discourse can present features of different types of talk, corresponding to different types of politeness rules and facework. Participants may experience and display emotions related to the way in which their faces are engaged in such interaction. These feelings are decisive for the group process of turning either to exploratory talk, cumulative talk or disputational talk. On the cognitive side, the emotions in play do not concern the subjects (participants) of the interactions directly, but rather the objects being discussed. The emotional framing of the problem is inherent to the process of schematization, which orients the discourse towards a given argumentative conclusion.

Still, this analytic approach remains simplistic compared to authentic occurring interactions. In order to better understand what happens when groups try to reason together, it is worth addressing the challenge of specifying the relations between these categories and how they can dynamically be influencing each other. From this perspective, two case studies are presented (4), showing a correlation between the type of collaboration that the students tend to develop in small groups and the emotional tonality characterizing their debate. This attitude questions the appropriate level of signified engagement, since discursively constructing the objects of the debate as more or less distant to the students seems to be related to how constructive the group interaction becomes. These results are consistent with previous literature. On one hand, the fact that cumulative talk is associated with low-intensity emotional framing confirms the need for minimal positive tensions to stimulate group work (e.g. Sins & Karlgren, 2013). On the other hand, the fact that disputational talk is associated with high-intensity emotional framing as well as direct implication of the subjects of the interactions reflects that people are either concerned by and/or feel responsible for the issue. This echoes the observation that feeling offended tends to inhibit group reasoning (Baker & Andriessen, 2009; Muntigl & Turnbull, 1998). These case studies led us to better integrate the social and cognitive functions of group emotions by questioning their relation. We finally propose a theorization of these results, on the basis of a representation of the links hypothesized for generalization.

Our first aim was to build conceptual tools appropriate for the study of socio-scientific debates among students, in order to make sense of our data. Retrospectively, we believe that this conceptual framework has a larger relevancy and deserves to be defined as a general theoretical approach that might be used in other contexts. This model might be useful for describing any situation in which a group is expected to reason together, either in educational or professional settings. Even if only long-term dialogue between scholars of multiple disciplines can fully achieve this goal, we consider this model as a first step toward the daunting challenge of theorizing how the social, the affective and the cognitive are intertwined in reasoning and learning.

Practical significance of the model and implications for design in CSCL

We would also like to emphasize a few implications of our model in terms of pedagogical design. First, we are doubtful of the restricted vision of emotion-regulation that promotes pedagogical strategies aiming at rescuing pure ‘cognitive processes’ by separating them from (detrimental) emotions that are considered to be markers of fallacious reasoning. Instead, it might be fruitful to make the participants aware of the social role of emotions, and provide them scaffolding for efficient collective regulation (e.g. Järvenoja & Järvelä, 2013). The benefits of emotion awareness applied to the cognitive functions of emotions are not as obvious. Case study 2, on French data (4.2) shows that group awareness of ‘warm’ cognitive conflict can lead to social-only relaxation strategies, encouraging disengagement.

We rather believe that consideration of the socio-affective dimensions, together with the cognitive, as fully integrated to the learning process must be embedded in the pedagogical situation itself. From a designer's perspective, understanding the cognitive emotions underlying students' engagement in more or less valuable forms of talk for educational goals is promising for fostering high quality student interactions. But in order to accomplish this, designers do not necessarily need to implement emotion-awareness tools, as extra marginal functions in their pedagogical environment. Indeed, optimal thymic framing should be reached as a cognitive necessity relying on the didactical challenge itself. Therefore, scaffolding students' optimal emotional engagement in the activity can be addressed, for instance, by a careful choice of topics as well as attention to how the target knowledge is contextualized. Designers should also include socioaffective concerns in their global *scripting* of the activity (Weinberger, 2003; Dillenbourg & Jermann, 2007), and not as an additional complementary tool.

Discussion and directions for future work

The proposed model has proved useful for deeply analyzing our data and has allowed us to formulate more general hypotheses on the relations between social and cognitive functions of emotions in groups trying to reason together. Some aspects still need to be confirmed by future studies. The correlation observed between group talk and the level of thymic intensity, in terms of emotional framing, is not sufficient to draw firm conclusions on the nature of causality between the two phenomena. In the presented case studies, arguing in favor of this relationship, we mainly focused on the intensity axis of emotional framing, and more specifically, on the distance from the issue. Further work on other data, and/or extending the analysis to other parameters of emotion construction on the cognitive side, including the valency axis, are needed to specify this relationship.

In addition, we would like to specifically highlight two lines of research for which our model can serve as a basis. First, at the theoretical level, the matter of building a global understanding of how cognitive, social, and affective dimensions of reasoning are integrated requires further work. For instance, a common argumentative practice is the use of ethos-based strategies to defend a claim. In such discourse, the distinction between the *subjects* and *objects* of conversation vanish, since subjects themselves become a discourse object to a great extent. Studying this type of frontier case would be interesting to better understand how cognitive and social functions of emotions get intertwined.

Our second focus for discussion and further investigation concerns educational practice. Here, the question is how can an optimal thymic framing for reasoning be defined and successfully reached in educational design? Can the thymic level of a debate be constrained, and how? On the social side, by rendering politeness rules explicit, transforming them through role play, or by choosing specific group formation (avoiding or favoring work among friends, or mixing students in terms of gender, academic results, social class, etc.) can be explored as potential ways to develop emotions beneficial for the targeted educational goals. However, it seems more difficult to find strategies that may directly influence the cognitive function of emotions in schematization. On that point, the history that the group and the individual members have with the topic, together with the media and social interdiscourse (Amossy, 2006, p. 94-99) that structures both pre-existing representations and feelings about them must be taken into account. Concerning this aspect, research reports on experiences of how school treats socio-scientific issues involving media analysis seem particularly interesting (e.g. Jimenez-Aleixandre, 2006).

Appendices

A. Transcripts of two discussion phases at table 2, Kenosha, USA, May 2012.

A.1 Kelly, Sabrina, Louise, Pamela's debate on OQ1:

1.	AMY	[&and it starts now\
2.	PAM	[i think it's
3.	LOU	B:\
4.	PAM	(((looks at LOU then the screen))
5.	KE	(((looks at the screen))
6.	LOU	cause i feel like people waste a lot of water
7.	KEL	yeah
8.	LOU	like washing [their dishes like&
9.	PAM	[yeah:\
10.	LOU	&before they put them in the dishwasher [brushing your teeth
11.	KEL	[or showers
12.	SAB	yeah\
13.	LOU	[showering
14.	PAM	[sho[wers yeah\
15.	KEL	[they take long (.) showers
16.	SAB	((nods head in the affirmative))
17.	SAB	<((nodding head in the affirmative)) uhuh>
18.	PAM	or like=
19.	LOU	=or just like other stuff
20.	PAM	people like when they brush their teeth (.) they leave the water running/ or like you wash your face whatever
21.	SAB	<((nodding head in the affirmative)) uhuh>
22.	KEL	((nods head in the affirmative))
23.	LOU	or like people that throw away like bottled water [or half the time like it's like it's not even finished and they'll just throw it away
24.	KEL	<((nodding head in the affirmative)) [yeah>
25.	LOU	[so i think it's [B
26.	SAB	[or they dump it out on the sidewalks
27.	KEL	or like washing your car
28.	PAM	yea[h:
29.	LOU	[oh yeah
30.	SAB	(((nodding head in the affirmative))
31.	KEL	[and then all the chemicals in it just go in the grass (.) <((turning head)) which is not good
32.	LOU	(((laughs)) ((rit))
33.	SAB	(((nods head in the affirmative))
34.	T2	((get away from the center of the table))
35.	SAB	(((stretches))
36.	LOU	(((stretches))
37.	LOU	<((stretching)) so do we agree [on B/ >
38.	KEL	[<((getting close to the stand)) so B\=>
39.	PAM	<((showing the stand with her finger)) put B on the thing>
40.	SAB	((puts letter B on the stand))
41.	LOU	(((stretches))

A.2 Kelly, Sabrina, Louise, Pamela's debate on OQ3:

1.	LOU	er: i think it should be priced by its quality because if [you'd have better quality it's just more work to like x it\
2.	KEL	(((nodding head in the affirmative, looking at LOU))
3.	KEL	em: there's more [production <((turning hands)) for it to>
4.	LOU	(((turning hands))
5.	LOU	yeah\
6.	KEL	yeah\

7.	KEL	[em:	
8.	SAB	[and what about (.) family income/ [you need water\	
9.	PAM	[yeah i also think D too 'cause like i don't think like less fortunate people should be (.) punished like you know what i mean like because they don't have money they pay for water they shouldn't (.) [not get water	
10.	LOU		[yeah
11.	SAB	time it's not their (fault)=	[xx
12.	LOU	=they could like they could overu:se like they could (.) not pay as much and [<((turning hands)) get more water>&	
13.	PAM		[and take advantage of that yeah: it's true
14.	LOU	&take advantage of it\ (.) when like it should be [<((swinging hands)) equal for all people>&	
15.	KEL		[(nodding head in the affirmative))
16.	LOU	&you know what i mean/ 'cause like in like it's their fault that they are (.) poor\ in a way because they could go find a job but they didn't like you know what i mean/	
17.	PAM	yeah	
18.	LOU	like i think it should be equal among everyone\ (3.8)	
19.	KEL	er:	
20.	LOU	er: i would say C but what are you guys [saying/	
21.	SAB		[what did you x the quality that was
22.	LOU	like [in a xxx water	
23.	KEL	[that's bad water or [the water	
24.	LOU	[xxx water is like more expensive than our like (gross) water which is more expensive than like	
25.	LOU	[(shrugs))	
26.	KEL	[it's because like it's like [processed more and like	
27.	LOU	[xxx water\	
28.	SAB		[(nodding head in the affirmative))
29.	LOU	it's processed more [and	
30.	SAB		[yeah\ i think it's either C or D\
31.	LOU	it actually takes work to go like get it and find out xx	
32.	MAR	okay so: [if you guys actually wanna pull up your letter now/ let's get started	
33.	SAB	[maybe C AND D\ 'cause [like	
34.	PAM	just pu- just put C:\	
35.	SAB	((taking card C))	
36.	KEL	put D\ no put C	
37.	MAR	you guys put your letters [up xx\ (0.8)	
38.	SAB	what/	
39.	KEL	i don't know:\	
40.	SAB	[we should put	
41.	PAM	[just put C and i'll explain like why we think D too\ (0.8)	
42.	KEL	yeah:\	
43.	SAB	<((putting card C)) well i'm putting C\>	
44.	LOU	C\ (0.8)	

B. Distance to the issue: key features from Klara, Isabelle, Asa and Samira's debates on OQ2 and OQ3.

In the following tables, are reproduced the parts of the transcript corresponding to the students' discursive construction of their emotional distance to the issue. Three parameters are

studied: the description of people concerned, the identification of people responsible for change, and the spatiotemporal distance to the issue.

During the group discussion about OQ2, no key marker of the spatiotemporal distance to the issue was identified.

Only one utterance described the people concerned:

OQ2 group discussion – people concerned	
speaker	utterance
ISA	c'est qui s'rait moins pollué/ <((se désignant)) c'est nous > (who would be less polluted/ <((gesture to herself)) it would be us\>)

On the contrary, the students extensively describe, during the group discussion on OQ2, the people presented as responsible of the evolution of the situation:

People responsible for change – OQ2 group discussion	
speaker	utterance
KLA	nan jamais moi \ (no i would never ever\)
SAM	<((à KLA)) arrêtes de faire aucun effort> (<((to KLA)) stop making no effort>)
KLA	moi j' fais pas l'C (i don't do the C\)
KLA	moi j'fais aucun des efforts hein\ c'est pas une personne qui va tout changer hein\> (i don't make any effort okay\ it's no one person who's gonna change everything okay\)
ISA	moi c'est la E\ y'a plusieurs personnes qui changent/ ça va changer\ (me it's E\ if several people change/ that would make a difference\)
KLA	moi j'en frais pas partie\ (i would not take part in it\)
SAM	si une personne (if someone)
KLA	c'est pas deux personnes qui vont tout changer quoi\ (it's not two people who are gonna change everything\)
ISA	plusieurs personnes ça va changer\ (several people that will make a difference\)
SAM	des gens ils sont feignants\ (some people are lazy\)
KLA	moi j'le frai pas\ (i would not do it\)
ASA	les gens (the people)
SAM	ils continuent à faire des véhicules et ils en achètent (they keep on making cars and they buy them)
ASA	on s'appelle pas tous samira et et klara hein\ (we're not all called samira and klara okay\)
ISA	qui commencent à l'faire (who start doing it)

SAM	j's'rais pas capable (i would not be able)
KLA	j'pourrais pas ne pas les changer (i could not not change them)
ASA	on va prendre moins douches (we're gonna take fewer showers)
ISA	si tu fais ces efforts-là (if you make that kind of effort)
ASA	le monde il est entouré d'vous (...) mademoiselle klara et mademoiselle samira (the world is surrounded by you (...) miss klara and miss samira)
KLA	moi j'f'rai aucun effort\ (i would not do any effort)
ISA	si on les arrêtaï (...) si on les écoutaï (if we stopped (...) if we listened to them)
SAM	mais ils arrêtent pas (but they don't stop)
SAM	personne n'arrête (nobody stops)
KLA	c'est pas nous qui changerions l'monde (it's not us who could change the world)
ISA	faut qu' t' essaies (you must try)
KLA	personne fait des efforts (nobody makes any effort)
ISA	qui commencent à arrêter (who starts to stop)
ISA	si on arrête (if we stop)
SAM	si on f'sait (if we did do it)

During the class debate that follows the group discussion on OQ2, the students keep on talking at their table. Below are reproduced the elements of their speech that contribute to the specification of an emotional distance to the issue:

speaker	utterance	key feature
KLA	ça va pas changer qu' y ait deux ou trois personnes (it will make no difference if there are only two or three people)	near future responsibility of others
SAM	y'aurait moins que la moitié (there would be less than half)	responsibility of others
ISA	trois millions d'personnes ça va changer (three million people that will make a difference)	responsibility of others near future
KLA	y'en aura mille alors (so there'd be a thousand)	future responsibility of others
KLA	si on est trois millions ça changera (if there are three million of us that will change)	future own responsibility
ASA	nous chronométrer dans la douche\ (timing us when we're having a shower\)	1 st person as both victim & responsible agent

ISA	si y'a plusieurs millions d'personnes (if there are several million people)	responsibility of others
ISA	s' ils le fraient (if they'd do it)	responsibility of others
SAM	c'est la nouvelle génération on est pourri gâté (it's the new generation we're totally spoiled)	current time own responsibility
SAM	à c't'époque (in these days)	current time
KLA	va trouver la foi en les gens (go find faith in people)	responsibility of others
ISA	y'en a plein qui le font (a lot of people do)	responsibility of others
SAM	on pense pas\ on pense à la vie\ (we do not think\ we do not think about life\)	own responsibility current time
KLA	moi mes besoins j'les f'rai (me my needs i will do them)	own responsibility
SAM	ma douche j'y passe trente minutes j'la ferai (i spend thirty minutes in my shower i'll do it)	own responsibility
ASA	s'chronométrer dans la douche\ (timing someone when he's having a shower)	people concerned: others
ASA	j' me réveille dix minutes tulutulu (i wake up ten minutes tulutulu)	1st person concerned
KLA	tu vas pas faire ça hein\ ça sert à quoi (you're not gonna do this\ what for/)	2 nd person as both victim & responsible agent
SAM	y'a du savon tu sors quand même\ (if there's still soap you still have to get out\)	2 nd person as both victim & responsible agent
SAM	mais à autrans euh nan j'sais plus quoi en russie ils étaient chronométrés deux minutes par douche\ (but in autrans er no i don't remember what in russia they were limited to two-minute showers)	far in space & people concerned
SAM	ils avaient moins d'cinq minutes\ (they had less than 5 minutes)	people concerned: others
SAM	en russie vous aviez moins d'cinq minutes (in russia you had less than 5 minutes)	far in space & time, 2 nd person concerned
KLA	t'es habituée à faire un truc tu vas pas changer (you're used to doing something your not gonna change)	own & everybody's responsibility
KLA	bah c'est la personne que t'es c'est la personne que t'es\ (that's who you are that's who you are\)	2 nd person as both victim & responsible agent

KLA	tu vas pas arriver avec en pat d'eph au bahut\ (you're not gonna come to school with bell bottom pants on\)	2 nd person as both victim & responsible
ISA	si les gens (if people)	others' responsibility
KLA	les pubs qu' ils font ça donne envie advertisements make people want things)	others' responsibility
ASA	s' chronométrer dans la douche\ (timing someone when he's having a shower)	others are concerned
ISA	qu'est-ce que j' frais sans mes bains moi\ (what would i do without my baths\)	1st person concerned
KLA	notre hygiène de vie (our daily hygiene)	1st person concerned
ISA	on va prendre les conséquences de nos actes\	near future, 1st person as both victim and responsible agent
KLA	moi j'vais pas changer pour les autres \ (i'm not gonna change for others\)	1st person responsible, others are concerned
ASA	pas pour les autres pour toi ta vie ta santé la santé de tes enfants \ pour tout\ (not for others for you your health your children's health\ for everything)	future, 2 nd person as both responsible agent and victim
ISA	enfants p'tits-enfants (children grandchildren)	far future, 2 nd person concerned (through others who are near)
KLA	j' vais pas changer mes habitudes à m'faire chier à faire pipi caca dans l'truc	1st person as both victim and responsible agent
SAM	on va pas mettre un chronomètre (we're not gonna get a timer)	1st person as both victim and responsible agent
KLA	faire chier mes parents (annoy my parents)	1st person as both victim and responsible agent (through near others)
KLA	au bout d'un moment j' le fais si y'en a vraiment b'soin\ mais là (after some time i'd do it if it was really needed\ but now)	future, own responsibility
SAM	t'es plein d'savon tit tit il faut qu' je sorte là ça a sonné\ (you're full of soap tit tit but you have to get out now it rang\)	1st person as both victim and responsible agent
KLA	moi j' change pas mon mode de vie pour l'eau (me i'm not changing my lifestyle for water)	1st person as responsible agent, no real victim

ASA	les efforts c'est qu' les gens ils arrêtent de mentir\ (main effort is when people stop lying\)	others' responsibility
ISA	t'arrêtes de laver ta voiture (you stop washing your car)	own and 2 Nd person responsibility
SAM	arrêter d'laver sa voiture (stop washing one's car)	everybody's responsibility
KLA	moi j' le fais pas (i'm not doing it)	own responsibility
SAM	tu vas laver avec (you gonna wash with)	own and 2 Nd person responsibility, near future
KLA	tant qu't'es pas allée dans l'futur (as long as you didn't go into the future)	future

The class debate about OQ2 is also an opportunity for some of the students in the studied group to make public contributions to the discussion. The parts of their speech that frame their distance to the problem only consider the parameter of the responsible agents for the evolution of the situation. They are reproduced below:

speaker	utterance
KLA	personne changera\ (nobody will change)
SAM	personne (...) fait quelque chose\ (nobody (...) does anything\)
SAM	personne va l'faire\ (nobody is gonna do it\)
ASA	°samira° (°samira°)
SAM	certaines personnes vont l'faire\ mais pas la majorité \ (some people would do it\ but not the majority\)

The discussion of the OQ3 is also an opportunity for the students to elaborate on their emotional distance to the topic. First, they do so during the group debate:

speaker	utterance	key features
KLA	les gens ils font une réserve (people they make a reservation)	others' responsibility
SAM	on est tous égaux et au fond on est tous des humains \ on a tous les mêmes droits\ (we are all equal and in the end we are all humans\ we all have the same rights\)	people concerned : everybody
SAM	en afrique ils ont pas d'eau\ (in africa they don't have water\)	far in space and others are concerned
KLA	ils ont rien\ pourtant ils paieraient quoique (they don't have anything\ they would pay though unless)	3rd person victim and slightly responsible agent
SAM	ils ont d'l'eau (they have water)	others are

		concerned
SAM	ça dépend des états (it depends on the country)	far spatial distance
ASA	abuse pas (don't exaggerate)	2 nd person responsibility
ASA	et après on perd des et après on perd (and after we lose some and after we lose)	1st person concerned
ASA	elle veut être démocratique vas-y vas-y (she wants to be "democratic" go ahead go)	2 nd person responsible
SAM	l'eau ils la vendent plus cher\ pour gagner plus\ (they sell water at a higher price\ to earn more\)	others' responsibility
SAM	ils devraient vendre au prix (they should sell it at cost)	others responsibility
ISA	ton robinet (your tap)	1st person concerned
ISA	si tu paies tout (if you pay everything)	2 nd person concerned

Klara, Isabelle, Asa and Samira, during the class debate about OQ3, either directly contributing, or making aside commentaries at the group level, keep on framing their distance to the issue:

speaker	utterance	key features
ISA	parce que si tu utilises pas beaucoup d'eau et qu' tu paies rien (because if you don't use a lot of water and you don't pay anything)	2nd person as both vicim & responsible agent
ISA	si t'es t' utilises beaucoup d'eau et tu paies le même prix qu' si t'en utilisais pas beaucoup (if you use a lot of water and you pay the same price as if you were not using a lot)	2nd person as both victim & responsible agent
ISA	si tu utilises pas beaucoup d'eau (if you don't use a lot of water)	2nd person responsible
ISA	si t' utilises pas beaucoup d'eau et qu' tu paies un prix comme si t'en utilisais beaucoup (if you don't use a lot of water and you pay a price as if you were using a lot)	2nd person as both victim & responsible agent
ISA	en afrique l'eau elle coûte cher/ (in africa the water is expensive/)	far in space
ASA	après ça dépend des (after it depends on the)	far in space
SAM	on la vend un peu plus cher (we sell it a a little higher price)	responsibility of sellers
ASA	dans une même ville y'en a qu'i's'ont plus d'eau que d'autres\ (in the same city some have more water than others\)	far in space (still africa), others are concerned
ASA	d' autres (others)	others are concerned

ISA	ils paient cher/ (do they pay a high price/)	others are concerned
ISA	vu que c'est très sec (as it is very dry)	far in space
ASA	où nos grands-parents ils habitent (...) au bled (where our grandparents live (...) in the village)	near to Asa, far from others, for people concerned, far in space
ASA	(where there's no water problem): allemagne (...) Amérique (...) france (...) royaume-uni (germany (...) united states (...) france (...) united kingdom)	far in space
ISA	si l'eau était chère en afrique (if the water was expensive in africa)	far in space
ASA	bah ça dépend des endroits (so it depends where -in africa)	far in space
ISA	au sénégal (in senegal)	far in space
ASA	elle est chère à dakar (is it expensive in dakar)	far in space
ASA	j'ai pas payé d'eau quand j'suis allée\ (i did not pay for water when i went there)	others are concerned

C. Transcript conventions.

Here are details the main transcript conventions used in this article:

[beginning of speech overlap
:	elongated sound
<((laughing)) uterrance>	commentaries on simultaneous coverbal behaviour
&	continuation of a speech turn
=	rapid succession of words/sounds
SPE ((turn))	non-verbal turn (laugh, gesture, etc)
xxx	inaudible segment
/ or \	rising or falling intonation
(word)	uncertain transcription
°word°	low voice
WORD	augmented volume
‘	non standard elision

Notes

¹ They were especially trained during 1 day (6 to 8 hours) in order to moderate the *café*.

² Caffi and Janney (1994) oppose the two adjectives *emotional* and *emotive* to distinguish between what is felt (*emotional*) and what is discursively expressed (*emotive*). In practice, the relation between *expressed* and *felt* emotions is problematic and can vary depending on the context. In this branch of argumentation studies, researchers usually claim that they focus on

the *expressed* emotions, basing their findings on discursive material, but often there is no evidence that *expressed* emotions actually differ from *felt* emotions.

³ *Facework*, the activity of seeking to preserve one's own and others' face, or positive social value (Goffman 1974; Brown & Levinson 1988), is a structuring element of interactions, which leads the participants to obey a politeness code that constrains the development of the dialogue.

³ This observation can be nuanced by the concept of 'argumentative politeness' that comes from argumentation studies. The specificities of argumentative interaction with respect to the matter of face preservation led to the characterization of a particular argumentative politeness system, which follows different rules than the ordinary system (Plantin, in press, p. 368-369). Then, disagreement is usual and is neither polite nor impolite, but rather 'a-polite'.

⁴ The debate in psychology about the direction of causality between emotional symptom and felt emotion is embodied by the classical James/Cannon opposition (Cosnier, 1994). A well known psychology experiment illustrates how forcing a smile (e.g. holding a pencil in one's teeth) can create the same internal physiological phenomena as smiling naturally *because* of an emotion (Soussignan, 2002).

⁵ Two other isolated occurrences of third person use present distinctive characteristics. One is Klara's mention of the role of her parents in changing habits at home. Here we are typically in a "near other" construction. It also constitutes a transfer of responsibility, reminding the group that adults have more potential impact on the problem than the students may have. The other isolated occurrence is also attributed to Klara, during group debate on opinion question 3. Her formulation is ambiguous as she talks about the people lacking access to water in these terms: "ils paieraient quoique" (they would pay unless). It tends to present them as responsible for their exclusion to water access due to the fact that they may not pay the corresponding price. The *topos* of the poor people being responsible for their status is not developed here, but it is a *leitmotiv* in our data (XXXX, 2014, 282-298).

⁶ Conversational turns are not numbered here because it's an inventory of discontinuous occurrences. The (...) stands for the discontinuity between the reported turns.

⁷ This is our own translation from French to English, focusing on the global meaning and level of language rather than trying to literally transpose French expressions.

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Fostering learning and collaboration in a scientific community – evidence from an experiment using RFID devices to measure collaborative processes

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Abstract: In this study, the integration of new members into a scientific community that comprised to a large extent members from the CSCL community was investigated. New members usually lack the necessary knowledge to interact successfully with more experienced members of a scientific community and to find collaboration partners. We investigated how the level of community participation and support for community knowledge were related to the building of new collaborative relationships during a scientific conference. Participants' interaction behavior was tracked using RFID devices; social network questionnaires and a bibliographic analysis provided additional data. We found that newcomers do not interact less with other participants than experienced members, but develop fewer collaborative relationships. The chances that newcomers' interactions lead to the building of new collaborative relationships were increased by access to explicit relevant community knowledge. Making such knowledge explicit seems to be a useful means for supporting newcomers in scientific communities.

Integrating new members into the CSCL community

The CSCL research community has already been the object of research in the past. We have learned that it is a broad interdisciplinary community comprising researchers from more than 11 disciplines who are distributed all over the world but with a majority in North America and Europe and a growing number of members in Asia (Hoadley, 2005; Kienle & Wessner, 2006; Stahl, Spada, Miyake, & Law, 2011). We know that there is an ongoing discussion about what CSCL is, what it comprises, and what a common and shared theory could be; also perspectives on the community differ between members of different geographical locations. Nevertheless, Hoadley (2005) found that the CSCL community consists of a stable core of leading persons. Also a stabilizing trend of CSCL conference participants was observed in 2006 (Kienle & Wessner) which might be seen as a sign for a maturing community.

A healthy scientific community must constantly integrate new members to secure its existence and to bring new ideas in. However, it was observed at previous CSCL conferences that a large percentage of newcomers participated only once and did not participate in later conferences (Kienle & Wessner, 2006). This might be considered an alarming sign and the community might wish to take actions to change this situation and focus more on the

integration of new members. So far, research on scientific communities is mostly based on bibliometric analyses focusing on co-authorship or citation analysis of conference proceedings or journal papers (see for example Hoadley, 2005; Newmann, 2004; Lee, Ye, & Recker, 2012). However, papers are artifacts that become only available to the scientific community with a large timely distance to their creation and many factors mediate between the publication of a paper and the beginning of a collaboration between members of the scientific community. To identify those factors that are directly related to the integration of newcomers, such bibliographic analyses are therefore not the optimal choice. For this reason, we conducted a study using a new approach to measure collaboration: RFID devices that all participants of a conference wore and which tracked their interaction with other participants. The aim of this study was to investigate what happens during scientific meetings and how the integration of newcomers can be fostered at such occasions.

Scientific Communities and New Members

The CSCL community can be seen as a scientific community, which is a special form of a community of practice (Kienle & Wessner, 2006). Kienle and Wessner (2005) collected essential characteristics of scientific communities: They consist of a heterogeneous group of members who are usually involved in several scientific communities and are therefore used to switching roles, from expert in one scientific community to less experienced in another scientific community. Members of scientific communities are often geographically distributed and belong to different organizations; in the CSCL community, members are even located across the whole world, although most members can be found in North America and Western Europe (Hoadley, 2005; Kienle & Wessner, 2006). In many scientific communities, members have backgrounds in different disciplines and scientific cultures, resulting in the use of different methods and theories. What brings them together is a joint field of research interests. Communication and interaction mostly takes place via written artifacts like journal publications and using computer-mediated channels, but there are also regular opportunities for face-to-face meetings, usually organized in the form of conferences and workshops.

Wenger, McDermott, and Snyder (2002) distinguish different levels of community participation in communities of practice located in and across organizations: outsiders, peripheral members, active members, and core members; in addition, some communities of practice have a coordinator. For scientific communities, these participation levels were adapted (Kienle & Wessner, 2005). Outsiders are person who do not intend to contribute to the scientific community, but benefit from its work; for example by reading single papers and maybe exporting ideas and results from them to another scientific community. Peripheral members are, according to the original model, persons who contribute only sporadically to the community and often lack the abilities and knowledge to contribute to more complex tasks. Therefore, newcomers to a community usually start as peripheral members. In a scientific community, peripheral members could be graduate students preparing their first papers but also more experienced researchers who explore a research field that is new to them. While focussing only on observable contributions to conferences, Kienle and Wessner (2005) suggested viewing only passive conference participants as peripheral members. Following

that rule, they defined all paper authors as active members. This is, however, only one possible way to conceptualize this participation level as the transition between peripheral and active membership is smooth and graduate students who wrote and presented their paper could still be seen as peripheral members in the first learning stage. Active members usually are defined as those persons who regularly contribute to a community and have the necessary knowledge and skills to do so. Core members are those active members who additionally take over substantial responsibility for the whole community and make efforts to influence its directions. In a scientific community, this can include conference program organizers, journal editors, or scientific board members.

Communication and Collaboration in Scientific Communities

In scientific communities, especially in interdisciplinary ones, successful collaboration can be understood as one of the most desired results of researchers' learning and of the scientific community's cohesion. Successful interdisciplinary collaboration in a scientific community requires an integration of the contributing disciplines on some level, for example the mutual integration of concepts, theories, methodologies, and epistemological principles (van den Besselaar & Heimeriks, 2001). The development of mutual understanding and the building of shared representations are important for fruitful communication between experts of multiple domains (Fischer, 2000).

To enable an individual researcher to benefit from and collaborate in a scientific community, this person must to some extent be integrated and has to acquire several types of knowledge that are shared in the community. Successful collaboration requires shared knowledge, including several different types of relevant knowledge, for example about contents or methods, but also about attitudes in the community as well as about the individual members (Cannon-Bowers & Salas, 2001). However, peripheral members usually have only little knowledge about the new community and need to acquire it first to become able to contribute more and in a proper way (Levine & Moreland, 1999). Compared to mono-disciplinary communities, this might be even more complicated in multi- and interdisciplinary communities because of the variety of research lines. The CSCL community still is divided on several questions, no underlying theory or methodology can be found on which all members would agree as being the basis of CSCL. Attitudes and beliefs of a community are even harder to grasp as they are usually not made explicit. Knowledge about individual community members seems comparably easy to acquire as most CSCL researchers present their bios and publications on their website. But for a newcomer, it is hard to identify the 'important' persons in a community or those who could be relevant for their own work. This makes it hard for newcomers to gain relevant knowledge about content, methods, community attitudes, and members within CSCL on their own.

A usual way to learn about a scientific community is reading papers. But to read only some of them can give a peripheral community member a very biased idea of the community. In this respect, face-to-face meetings are of high relevance to scientific communities; among other things, they provide possibilities for peripheral members to gain community knowledge and

interact with other members. Such meetings make communication easier, especially in scientific communities like CSCL which consist of members with different native languages complicating the distribution of results and effective communication (Kienle & Wessner, 2005). Workshops and conferences are used to foster researchers' communication and learning about the findings and approaches of others, but also to integrate newcomers. Such events bring participants together and allow them to focus on learning activities and on community building, and can be called encapsulation. Although encapsulation is a widely used strategy in different contexts (Levine & Moreland, 1991), it can be organized in different ways: workshops usually allow for more one-on-one interaction, while (larger) conferences usually focus on other types of communication. However, it is unclear how one-on-one interaction is related to researchers' learning in the scientific community. Access to community knowledge, especially to knowledge about other members, seems in particular to be also very relevant and it might be helpful to foster it during encapsulation events.

In this study we investigate factors which influence the integration and learning of newcomers in a scientific community. We adopt a social network perspective on learning and integration by focusing on the building of collaborative relationships between community participants as the visible and desired consequence of integration and learning. The social network approach offers two different ways to look at the building of collaborative relationships. First, we can look at individual persons and how successful they were in building new relationships; second, we can also look at all individual relations between two community members and what factors influence the probability of a random relation to become a collaborative relationship:

1. Persons-related RQ: To what extent can support for community knowledge and participants' level of participation predict a participant's number of newly built collaborative relationships?

2. Relation-related RQ: To what extent can time spent interacting, support for community knowledge, and a persons' level of community participation predict the development of a new collaborative relation?

Method

Study Design, Context and Participants

The study was planned with a quasi-experimental design in which the factor *support for community knowledge* was varied across different workshops and the factor *community participation level* varied naturally among participants. This design was implemented at a small conference organized by a European research community which is closely related to the CSCL community. The aim of the conference was to bring together researchers from multiple disciplines who worked in the field of technology-enhanced learning. The conference was organized in a non-standard way and consisted of 8 workshops and a doctoral consortium. The workshops were organized in two series of 4 workshops taking place in parallel. The number of participants for each workshop varied between 14 and 22 persons. Each workshop lasted one and a half days while the doctoral consortium lasted for the whole 4 days. The conference took place at a hotel in a remote place and all workshop organizers and

participants also lived in this hotel during the time. Participants were selected based on a review process of papers they had submitted.

All together, 152 persons participated in the conference. The majority of them came from European countries, but there were also participants from many other countries. For this study, only persons who had participated in one of the workshops were taken into account. Persons who were only involved in the doctoral consortium were left out because of their special conditions during the conference. Also the data of participants who had missing values or whose answer patterns made their credibility questionable was left out. For the analysis of the two research questions, further constraints (explained below) resulted in different sample sizes. For RQ 1, the sample consisted of 89 participants. For RQ 2, the sample consisted of 742 dyadic relations in which 125 persons were involved.

Data Collection and Instruments

Data about the participants' interaction during the conference, their collaborations with other participants beforehand, and their intended collaborations after participation to a workshop were measured using two different tools: RFID devices and social network questionnaires. Further information about the participants was taken from the application form for the conference. Additionally, a bibliographic analysis of co-authorships listed in Google Scholar was performed.

Tracking face-to-face proximity with RFID devices

During the conference, each participant wore an RFID device, developed by the SocioPatterns collaboration (<http://www.sociopatterns.org>) that was integrated into the name badge. The devices engage in bidirectional low-power radio communication. As the human body acts as a shield for the used radio frequency, and as the badges are worn on the chest, badges can exchange radio packets only when the individuals wearing them face each other at close range (about 1 to 1.5 m). The measuring infrastructure can capture that there was a close face-to-face proximity between two individuals with a temporal resolution of 20 seconds, and gives therefore access to the amount of time that two participants spent together (see Cattuto et al. (2010) for a detailed description of the infrastructure). Only two participants of the conference declined to wear the devices.

Social network questionnaires

After each workshop, participants were asked to fill in a social network questionnaire about their relations within the workshop: they were given a list of all workshop participants' names and were asked to indicate with whom they had collaborated already before the conference and with whom they had found potential for future collaboration. As some conference attendees participated in two workshops, 160 questionnaires were handed out, from which 150 were returned.

Bibliographic analysis on publications listed in Google Scholar

About 1.5 years after the conference had taken place, we performed a Google Scholar search to have an indicator if the subjective indications in the social network questionnaire had lead to an objective measurable collaborative outcome.

To identify if two participants had collaborated with each other before but forgot to indicate that in the social network questionnaire, we performed a search for joint publications before the conference. We restricted this search to papers published in 2010 or earlier (query term: “as_yhi=2010”). For each author’s name, at least two variations were included (query term: “(author: Doe J OR author: Doe John)”). For each possible pair of workshop participants, a separate search was conducted by combining them, for example the query term “(author: Doe J OR author: Doe John) AND (author: Smith S OR author: Smith Samantha)”.

To identify joint papers after the workshop, we performed a second Google Scholar search similar to the first one, but restricted to papers published in 2011 or later (query term: as_ylo=2011).

Dependent and Independent Variables

Level of prior community participation

Each participant was allocated to a community participation category, either as a peripheral community member or as an active community member. The allocation was based on the participant’s previous participation in the scientific community (similar to the allocation criteria used by Kienle and Wessner, 2006). Those participants who fulfilled at least one of the following criteria were assigned as active members: they attended the previous conference 1.5 years ago, they were organizers of one of the workshops at the present conference, or they were members in one of the boards of the scientific community. Peripheral members fulfilled none of these criteria.

Access to community knowledge

In 3 of the 8 workshops, support for community knowledge was given with the aim to foster collaboration between participants. Support for community knowledge was implemented as knowledge about the individual community members. A brochure with the following information about all participants was compiled: their name, picture, contact information, affiliations, background, research interests, and exemplary publications. This brochure was handed out to the participants at the beginning of the workshop without further instructions.

Number of newly built relationships

To answer RQ1, we computed for each person the number of new collaboration partners. Participants with whom the person had already collaborated before the conference were not included as new collaborative relationships; this was either indicated by the person, the partner, or both of them in the questionnaire or by previous collaborative publication between the person and the partner found in the bibliographic analysis. Three different types of newly

built relationships were computed based on different measures: the number of new interaction relationships, the number of new subjective collaborative relationships, and the number of new objective relationships.

Number of new interactive relationships. The number of new interaction partners was computed for all persons from their face-to-face time with other workshop participants (recorded by the RFID infrastructure). All participants of the workshop with whom a person had interacted during the workshop (but not collaborated before the workshop) were counted.

Number of new subjective collaborative relationships. This outcome variable was computed from the social network questionnaire. We counted the number of participants with whom the particular person had indicated to have identified potential for future collaboration, but only if the respective participant had also indicated to have identified potential for future collaboration with this person.

The sample for RQ 1, in which the number of newly built relationships was the outcome variable, included only a sub-sample of the conference participants. Only those participants were taken into account who had indicated in the questionnaire to have not collaborated before with at least 10 of the other workshop participants. This constraint was made because of statistical reasons: A person who had only the chance to build a new relationship with 2 other participants of the workshop (because he or she had collaborated with all others before) would bias the results because this person might have built more new relationships if possible.

Interaction time

Interaction time was computed for each dyad of participants in a workshop. The time was taken from the RFID-based measurements. For the relations within one of the 4 workshops in the first part of the conference, only the interaction time from the beginning of the conference to the end of the workshop was taken into account. For the relations within one of those 4 workshops that took place in the second part of the conference, only the interaction time from the beginning of the workshop until the end of the conference was taken into account. Observed interaction times between pairs of participants ranged from 0 seconds to 75 minutes.

Development of a new collaborative relation

To answer RQ 2, we analyzed all possible new relation between two participants of the same workshop who had not collaborated with each other before. Therefore, relations were excluded if one or both persons in the relation had indicated in the social network questionnaire to have collaborated with each other already before the workshop or if a previous joint publication was identified in the bibliographical analysis. Three different types of possible new relations between two participants were computed based on different measures; all three types were dichotomous variables: the development of an interactive relationship, the development of a new subjective collaborative relationship, and the development of a new objective relationship.

Development of an interactive relationship. If a face-to-face interaction had been recorded with the RFID devices measurement between two persons who formed a possible new relation, this was taken as a newly developed interactive relationship (= 1). If no face-to-face interaction was recorded, the relation was treated as one without a newly developed interactive relationship (= 0).

Development of a new subjective collaborative relationship. If both persons in a relation had indicated in the social network questionnaire to have identified potential for future collaboration after the workshop, this was taken as a newly developed relation (=1). If none or only one of the two persons in the relationship had indicated to have identified potential for future collaboration, this was seen as no relationship (= 0).

Development of a new objective relationship. Taking the results of the Google Scholar search of co- authorships, we looked for each possible pair of two workshop participants, if they had published a joint paper after the conference. If a joint paper was found this was taken as newly developed objective relationship (= 1). If no jointly published paper was found, this was taken as no newly developed objective relationship (= 0).

Data Analysis

To answer RQ 1, the data was analyzed using hierarchical linear modeling and applying a HLM model (using the software HLM 6.08 by Raudenbush, Bryk, and Congdon, 2004) as each person was nested within a workshop. HLM allowed us to control for random effects caused by differences in the workshop which could not be controlled otherwise. As the dependent variable was Poisson-distributed, a logarithmic link function was used.

For RQ 2, instead of looking at the outcome of individual persons, we looked at the *relations* between two persons. In this way, data of the same person appeared several times in the dataset and the relation-data was cross-classified within two persons. To control for person-specific effects we used a HCM2 model (using the software HLM 6.08). Each relation appeared twice in the dataset, so each of both persons in a relation was identified as cross-classification variable twice. After carrying out the analysis, we divided the degrees of freedom in half again to deliver appropriate results for the real sample. Additionally, it was necessary to apply a logarithmic link function to the model to account for the binomial (dichotomous) distribution of the outcome variable. Additionally, a χ^2 -test was applied to investigate the development of new objective collaborative relationships because the percentage of identified new objective collaborative relationships was too small to apply HCM here as well. For all analyses, the significance level was set to .05.

Results

Person-related RQ1: Influences on a person's number of new interactive relationships. No significant effects of community participation level, support for community knowledge or of an interaction of those variables on the participants' number of interaction partners during the workshops could be identified.

Person-related RQ1: Influences on a person's number of new subjective collaborative relationships.

The population-average model to predict a participant's number of new collaboration partners after the workshop revealed the following results: An average participant who was an active member of the scientific community and had not received support for community knowledge acquired on average 3.4 new collaboration partners ($\gamma = 1.222$, $SE = 0.142$, $t(7) = 8.622$, $p < .01$). Peripheral community members, in contrast, acquired on average only 2.0 new collaboration partners ($\gamma = -0.319$, $SE = 0.153$, $t(86) = -2.087$, $p = .04$). However, peripheral community members who received support for community knowledge were able to find on average 3.6 new collaboration partners ($\gamma = 0.437$, $SE = 0.213$, $t(86) = 2.051$, $p = .04$). No significant effect of support for community knowledge was found on active community member's number of new subjective collaborative relationships.

Relation-related RQ 2: Influences on the development of a new interactive relationship. The HCM model showed that for two random participants of a workshop who did not receive support for community knowledge, the average probability to develop a new interactive relationship was 30.3 % ($\theta = -0.832$, $SE = 0.150$, $t(698) = -5.541$, $p < .01$). This probability varied significantly across individual workshop participants. If they received support for community knowledge in their workshop, their probability to develop a new interactive relationship was significantly reduced by 10.3 % ($\theta = -0.551$, $SE = 0.235$, $t(698) = -2.340$, $p < .01$). No significant effect of community participation level was found on the probability to develop a new interactive relationship.

Relation-related RQ 2: Influences on the development of a new subjective collaborative relationship.

We identified the following HCM model to predict the probability of a random relation between two workshop participants to develop a new subjective collaborative relationship after they had participated in the same workshop: If both persons were active community members and they had not interacted face-to-face with each other, their probability to mutually identify potential for future collaboration was on average 27.9 % ($\theta = -0.948$, $SE = 0.162$, $t(697.5) = -5.861$, $p < .01$). However, this varied significantly across individual persons. For every minute two persons spent interacting, the probability for them to develop a new subjective collaborative relationship increased significantly (θ (in seconds) = 0.001, $SE < 0.001$, $t(697.5) = 2.057$, $p = .03$). For example, a relation in which the two persons had spent 1 minute interacting with each other, had an increased probability to develop into a new subjective collaborative relationship by 1.2 % compared to a relation in which no direct interaction was measured. If one of the two persons was a peripheral member, the probability for the relation to develop into a new subjective collaborative relationship was significantly reduced by 6.7 % ($\theta = -0.361$, $SE = 0.197$, $t(697.5) = -1.836$, $p < .04$). No significant effect was found for support for community knowledge.

Relation-related RQ 2: Influences on the development of a new objective collaborative relationship.

There was a significant difference between the relations of participants who had received support for community knowledge and those relations in which no support was available regarding the development of new objective collaborative relationships ($\chi^2(1,699) = 21.11, p < .01$) favoring those who had received the means of support. No significant differences were identified between peripheral and active members. Also no significant difference was found between relations in which persons had directly interacted with each other and those without direct interaction during the workshop. No difference was found as well between those relations in which a subjective collaborative relationship was reported and those in which no such relationship was reported.

Conclusion

Encapsulation events like conferences and workshops are an important means of scientific communities to bring their members together and foster integration of new members. Therefore, peripheral members of scientific communities are an important group of participants. Although peripheral community members seem not to differ from active community participants regarding the number of interactions they have during a conference or the probability for interacting with a random other participant, they seem disadvantaged regarding the outcome of these interactions. Peripheral members' chances to develop subjective collaborative relationships are lower resulting in a lower number of new subjective relationships after the conference. However, we do not find these results in the more objective measurement on real collaborative outcomes, but this might be due to the fact that measuring joint papers 1.5 years after the conference is still a bit early. The process to plan a joint research project, collect and analyze data, write a paper and successfully publish it takes usually a long time and it seems advisable to rerun a Google Scholar search at a later point in time.

In this study we assumed that the disadvantages of peripheral community members could be based on their lack of community knowledge. Therefore, we supported the participants of some of the workshops with explicit community knowledge. Providing participants with this support reduced the chances that a participant interacted with a random person, but did not reduce the number of their interaction partners during the conference. This can be seen as a hint that participants who had the community knowledge support were able to identify more precisely who would be a relevant interaction partner and enabled participants to use their few time more efficiently by focusing on interactions with those participants. This is in line with the result that the longer two persons spent interacting with each other, the higher their chances to build a new collaborative subjective relationship. However, our community knowledge support was not directly related to the chances for building a new subjective collaborative relationship or the number of newly built subjective collaborative relationships. Looking at the few results of joint papers we identified so far, we see a clear relation between receiving community knowledge support and successful objective collaborative relationships. Taking all these results together, we can assume that community knowledge support enables participants of scientific meetings, especially those who still possess little community knowledge, to identify promising partners for collaboration more efficiently and to focus on

longer and more effective interactions with those, which increases the chances of plans for future collaboration to become real and visible collaborations.

Additionally to the limitations of the objective collaborative relations measurement through our Google Scholar search, also some technical problems with the RFID devices have to be reported: we can not claim to really have measured all face-to-face interactions between workshop participants because some participants lost or forgot their RFID devices for some time or the devices run out of battery. Also, the name badges in which the devices were integrated flipped quite often, so the body of the participant wearing the badge shielded the radio signals. Although we surely missed some interactions between participants, the results show that RFID devices can work as a promising new method to measure collaboration. But researchers who want to use this technique in the future can surely improve its use by taking care of the reported problems.

Aside from technical questions, the results of this study confirm the importance of shared community knowledge for collaboration (Cannon-Bowers & Salas, 2001). The relation between community knowledge has so far been studied on the cognitive level, but our findings confirm them also from a social network perspective with visible outcomes. Acquiring shared community knowledge seems important for the building of new collaborations and the integration of peripheral members into a scientific community. Additionally, our results confirm finding from previous studies about tactics which can be used by communities of practice to integrate and support their newcomers and peripheral members (Eberle, Stegmann, & Fischer, 2012). This study had identified explicit access to community knowledge as an important means to foster the learning of peripheral members and foster their collaboration with more active members. This finding seems to be transferable to scientific communities as a special type of community of practice.

We can also draw some practical implications from this study for future CSCL conference and workshop organizers as well as for their participants: Organizers can support the integration of peripheral participants by providing explicit access to information about the community and its members and by planning for enough time for their participants to interact on a one-on-one basis with each other. Participants, on the other hand, can positively influence their workshop and conference experiences by informing themselves beforehand about the other participants and their backgrounds and by focusing on longer one-on-one interactions with other participants.

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