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Rainbow: A framework for analysing computer-mediated pedagogical debates

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Abstract In this paper we present a framework for analysing when and how students engage in a specific form of interactive knowledge elaboration in CSCL environments: broadening and deepening understanding of a space of debate. The framework is termed "Rainbow," as it comprises seven principal analytical categories, to each of which a colour is assigned, thus enabling informal visualisation by the analyst of the extent to which students are engaging in interaction relating to potential achievement of its pedagogical goal. The categories distinguish between activities that are part of the prescribed assignment and activities that are not, and between task-focused and non-task-focused activities. Activities focused on managing the interaction itself are distinguished from argumentative interaction. Notably, an operational definition of what it means to broaden and deepen understanding in this case is also provided here. The functional Rainbow analysis is

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complemented by an analysis of topics and subtopics that enables identification of one form of conceptual deepening of the question. In comparison with existing analysis techniques, Rainbow synthesises much of what is known into a single framework, with a broad theoretical base. The usability and educational relevance of the framework has been validated experimentally across a variety of collaborative learning tasks and communication media. Possible and actual extensions to the framework are discussed, with respect to additional CSCL tools, domains and tasks.

Keywords Argumentation · Collaborative learning · Debate · Interaction analysis · Methodology · Pedagogy

A significant amount of recent research on collaborative learning (CL), and computer support for it (CSCL), has been concerned with the study of interactions between students. This approach, broadly termed the "interactions paradigm" (Dillenbourg et al. 1996) is, however, very diverse in terms of (at least) conceptions of what interactions are, reasons for studying them, and thus theoretical and methodological approaches to their analysis (see, e.g., Stahl 2004). In this paper we propose a general framework for analysing one type of interaction between students in CSCL environments: debates. As an initial means of describing this framework, we shall briefly discuss some of these visions of interaction.

An "inter-action" is a series of actions that mutually influence each other. Human actions can be communicative or not, verbal or non-verbal, and expressed in a variety of media (speech, written language, graphical modes of expression, and so on). Mutual influence between actions, operating via the people who produce them, can function, for example, on physiological, epistemic, emotional and socio-relational planes. Mutual influence is a matter of degree, and relates in part to temporality: a more or less rapid exchange or emails, a set of contributions to a web-based forum, a CHAT exchange, a session of actions on a shared graphical workspace and a videoconference can all be more or less "interactive" in this sense. An interaction between human beings is thus intrinsically a dynamic process, functioning potentially and concurrently along all the dimensions of human joint activity. Computer-mediated interactions have specific characteristics, such as ability to revise messages, and their sequentiality, that influence the ways in which people achieve mutual understanding (Clark and Brennan 1991).

As objects of scientific observation, communicative interactions are reconstructed within particular theories and methods. The existence of video recording and possibilities for automatically tracing computer mediated interactions raise the question as to the nature of the primary interaction data under analysis: some kind of transcription, or the original data itself? Analysis tools now exist (e.g., Transana: Woods and Fassnacht 2007) that enable analysis codes to be ascribed directly to digitized video, in which case analysts are no doubt taking into account a wide variety of behavioural data in making their judgements. When transcriptions are done, these are necessarily selective, depending on the analysis approach to be applied to them, and this is also true of automatic computer tracing, where choices also have to be made as to what to trace and what not to trace.

In terms of a classical experimental approach, one reason for studying interactions between students has been to try to correlate their characteristics with differences in learning outcomes across experimental groups. This has motivated the search for so-called "productive" types of interactions (such as those where constructive conflict resolution, explanation and mutual regulation are preponderant). Very often, associated analysis methods are based on categories derived from some combination of speech act and problem-solving

theories. The categories are often designed to be discrete units, whose occurrences can be counted and applied in a repeatable way (as shown by measures of inter-coder reliability).

Other approaches consider the interaction itself as a process of socio-cognitive evolution, or "interactive meaning making" (Koschmann 2001), rather than as something that 'produces' subsequent learning 'effects.' Such work is often inspired by conversational analysis and dialogical theory, but also by social psychology, as in the case of the work of Trognon et al. (e.g., Trognon 1993; Trognon and Batt 2003). These researchers see cooperative learning as a process of appropriation of proposals from the interlocutor (when one participant uses a proposition of another as a premise for joint reasoning). Seeing discursive phenomena (such as explanation, argumentation, negotiation of meaning) in communicative interactions as processes *per se* is not easily reconcilable with the ascription of discrete analytical categories, since these phenomena often underlie extended interaction sequences.

A third reason for studying students' interactions is to inform design of interactive technologies. For example, the study of real interactions can bring to light a wider range of processes than are originally supported by the technology, and can, for example, help to identify 'problems,' relating to coordination and mutual awareness.

Finally, these three motivations are not necessarily mutually contradictory, even though in some cases their conjoint pursuit may involve theoretical eclecticism. For example, it is possible to analyse broad functional categories of interaction (such as those that are primarily concerned with social or task-related talk) in relation to learning outcomes, to also do a more fine-grained process analysis, 'zooming in' on certain segments, and to attempt to relate the analyses to recommendations for CSCL system re-design.

Although we discussed above reasons for and approaches to studying "interactions" in general, in (CS)CL research, in fact these fields have now attained a state of maturity that has justified focusing on specific *types* of interactions and discursive phenomena, such as argumentation (Andriessen et al. 2003a). This paper thus presents a specific framework for analysing a specific type of interaction produced in collaborative learning situations: *computer-mediated debates*. A debate is a *knowledge-based argumentative interaction* (Baker 1999), in which argumentation in interaction is engaged in order to answer a specific question by purely verbal means (i.e., the question cannot also be answered by manipulating objects, carrying out experiments, and so on, in the interactive situation itself). As will be discussed in subsequent sections of this paper, we see argumentative interaction as a process that is oriented towards deciding what statement(s) should be jointly accepted, or not, by linking those statements to others [called (counter-)arguments], and thereby transforming the degrees of acceptability of the statements under discussion (theses). Whilst argumentative interactions may arise in any cooperative problem-solving situation, in debates, argumentation is the *raison d'être* of the verbal interaction itself, as a means and medium for solving a problem. The analysis framework that we present here is called *Rainbow*, since it comprises seven principal categories, to which different colours are assigned for ease of visualisation of broad functional categories of interaction.

Rainbow was developed within the EU funded "SCALE" project (Support for Collaborative Argumentation-Based Learning—see footnote "*" at the beginning of this article), the aim of which was to develop web-based tools for argumentation-based collaborative learning. The principal aim of the analysis framework is thus to determine to what extent the students actually engaged in argumentative activities, and thereby attained the principal pedagogical goal of the situations that we designed, that of *broadening and deepening understanding of the space of debate*. As will be described later, this functional category corresponds to the seventh of rainbow, represented by the colour violet. Thus, the more the coded interaction goes towards the violet end of the colour spectrum, the more the

students' interaction is concerned with achieving the pedagogical goals of the situation, from the teachers' and researchers' point of view.

Rainbow was initially developed for the analysis of *quasi-synchronous computer-mediated interactions*, produced with a conventional CHAT system, and/or a tool for collective construction of argument diagrams (with the "DREW" tool,[1] Corbel et al. 2003). Analysis is carried out "by hand" (i.e., no automation at present) on the basis of automatically recorded interaction "traces," that time-stamp the reception of interface actions on the server (e.g., sending a CHAT message, creating an argument box or link). The fact that actions produced with such interfaces are relatively short, and contain no overlapping communication (contrary to most spoken interactions), make them amenable to the type of analysis carried out with Rainbow (as described below), requiring ascription of single categories to individual segments.

The principal methodological aim of the framework is to enable functional categories of interaction to be quantified (e.g., "social talk," "interaction management," "argumentation"), within an experimental approach, so that such frequencies of interaction categories can be correlated with pre–post test gains in understanding, and applied across different experimental conditions (involving, for example, either the use of CHAT or else CHAT with an argument graph tool). For these reasons, the categories were designed so that they could be applied by assigning unique 'labels' to specific segments of interaction (usually, but not always, speech acts within messages). Furthermore, for purposes of comparability, the same categories should be applicable to both typewritten and graphical argumentative interactions. As we discuss below, the set of analytical categories aims to synthesise much of what is known about communicative interactions, across a variety of theoretical frameworks (including dialogue, conversation and argumentation theory). Within what may be termed a socio-cognitive psychological approach, the Rainbow analysis categories are clearly "etic" (relying on extrinsic theoretical constructions that have meaning for the scientific observer) rather than "emic" (having meaning for the participants),[2] given our overall methodological approach. However, the interaction is categorised taking into account the extent to which the participants make manifest their mutual understanding, as it emerges from the interaction by a process of negotiation.

In the rest of this paper, we begin by discussing some related research on analysis methods for computer-mediated argumentative interactions. This is followed by a detailed presentation of the analytical framework, using illustrative extracts from CHAT debates (on the theme of Genetically Modified Organisms). Two sections follow, that present firstly, fundamental methodological issues arising in such interaction analysis, and secondly, possible extensions of the Rainbow framework. We conclude with a discussion of the specific research contribution of Rainbow.

Approaches to analysing computer-mediated argumentative interactions in collaborative learning situations

Since most recent research on (CS)CL involves at least some attempt to analyse interactions between students, and very often, the development of specific analysis techniques, the scope of interaction analysis methods in this context is now too large for a general synthesis

[1] Dialogical Reasoning Educational Webtool: http://drew.emse.fr. DREW contains a large variety of CSCL tools, including argument graphs and structured CHAT; they are not our concern here.

[2] The terms "etic" and "emic" originated in the work of the linguistic anthropologist Kenneth Pike.

to be viable in the present paper. Furthermore, there is now a very large literature on the developmental psychology of argumentation (see, e.g., Coirier and Andriessen 1999; Kuhn and Udell 2003; Leitão 2000; Voss 2001) that draws on a variety of argumentation theories (see van Eemeren et al. 1996). The specific argumentation theory on which argumentative categories of Rainbow are based (pragma-dialectics) will be dealt with below, in the presentation of the method. We shall therefore restrict our review below mainly to methods for analysing students' interactions that are *computer-mediated* and *argumentative*.

The recent work of Spada et al. (Meier et al. 2007; Spada et al. 2005) provides a useful starting point for review, to the extent that a method for evaluating "the quality of collaborative processes in CSCL" is proposed, which incorporates many aspects of effective collaboration. Nine fundamental dimensions of the quality of collaboration are described: (1) sustaining mutual understanding, (2) coordinating communication, (3) information pooling, (4) reaching consensus, (5) task division, (6) time management, (7) technical coordination, (8) shared task alignment, and (9) sustaining commitment. Trained raters were asked to analyse video recordings of dyads working together. Inter-rater agreement was not perfect, but acceptable. Moderate to high correlations were found between quality of collaboration and quality of solutions produced by collaborating dyads. The validity of the method was further shown by the fact that dyads that were instructed in how to effectively collaborate, in terms related to these same nine dimensions, outperformed non-instructed dyads. Interestingly, despite the fact that disagreement and argumentation are likely to occur in collaboration, and may be more or less productively resolved, the Spada et al. (2005) method does not explicitly refer to this as a dimension. To some extent, it is implicit in dimension 4 "reaching consensus," which refers to the necessity to critically evaluate information, in order to avoid a superficial consensus. As the authors point out, rater-analysts must make *holistic* or global assessments of dimensions of collaboration using this method, when watching videos of students: around two hours of rating time are required for one h of video. This is to be contrasted with fine-grained discourse coding schemes, such as "DISCOUNT" (Pilkington 1999), that can only be applied to transcribed dialogue data (as is the case with the framework described here).

The first comprehensive collective work devoted specifically to argumentation and CSCL is most probably Andriessen et al. (2003a). Surprisingly, relatively little of the work therein describes an explicit and developed method for analysing argumentative interactions, with the possible exceptions of Andriessen et al. (2003a, b), Baker (2003), van Bruggen and Kirschner (2003) and Veerman (2003). Baker's (2003) work, aims to analyse students' changes in attitudes (e.g., from "yes" to "no" or "?") towards segments of each other's texts, presented and revised in a CSCL environment, as a function of dialectical characteristics of the students' interactions (attacks, defences, concessions, requests for clarification, etc.), using an extended dialogic logic (Barth and Krabbe 1982). It was found that in such situations where students are searching for solutions, their attitudes almost invariably weaken (e.g., from certain acceptance to doubt). The research of Andriessen et al. (2003a, b) aims to understand processes of knowledge constitution and transformation, as they occur in both computer-mediated collaborative writing of texts and interactions (CHAT). As well as defining and applying argumentative categories (explanation, consequence, restriction and countering) these authors integrate such analysis with expression of information, elicitation and evaluation. Veerman's (2003) approach similarly integrates analytical categories for "constructive activities" (explaining, transforming) with those for argumentation (check, challenge, counter-argument). Her approach was applied to analysis of interactions produced with three different types of electronic media: synchronous CMC (Netmeeting), a synchronous evidence-based reasoning graphical

tool (Belvedere) and a thread-based forum. Van Bruggen and Kirschner (2003) similarly integrate argumentative categories (claim, support, qualify, deny, query) with non-argumentative ones, as a means of understanding how argumentation relates to attempting to solve "wicked problems" using support of external representations. Taken as a whole, the work presented in the abovementioned volume reveals the necessity to integrate analyses of knowledge elaboration and of argumentation in CSCL settings.

A framework that incorporates an even broader range of dimensions for analysing argumentative knowledge construction in CSCL has been described recently by Weinberger and Fischer (2006). Four dimensions are proposed: the participation dimension (quantity and quality), the epistemic dimension (construction of a problem space, a conceptual space and relations between the two), the argument dimension and the dimension of social modes of construction (different types of consensus building). The argument dimension is generally based on Toulmin's (1958) model.

A useful comparative synthesis of such analytical frameworks for "assessing dialogic argumentation in online learning environments" has been carried out by Clark et al. (2007). The synthesis focuses on five categories of frameworks: (1) formal argumentation structure, (2) normative quality, (3) nature and function of contributions in the dialogue, (4) epistemic nature of reasoning, and (5) patterns and trajectories of participant interaction.

As these researchers point out, Toulmin's (1958) model for argument layout has inspired many analysis approaches in educational sciences (e.g., Erduran et al. 2004). However, it gives little indication about field-dependent aspects, i.e., in a specific domain, what does or does not count as a datum for a conclusion? More generally, (and cf. remarks by Leitão 2000), the model is generally monological rather than dialogical: it is not so useful for representing a variety of viewpoints and oppositions between them. As we discuss later in this paper, however, any model of argumentation must retain a fundamental notion of Toulmin's model, which is that of the *warrant*, a general and generally accepted rule (that Aristotle termed a *topos*) that 'authorises' the transition from datum to conclusion, or argument to claim/thesis.

For many educational purposes it is important to evaluate the normative quality or correctness of argumentation. Whilst Toulmin's model is essentially descriptive, the diagrammatic analysis it provides can help to clarify argument structures precisely so that they may be more easily evaluated. For example, Kuhn and Udell (2003) aimed to measure development in students' argument skills over time. They propose a ranking of types of pro and contra arguments (for a specific topic: capital punishment), the lowest rank of which is "nonjustificatory argument" (e.g., justification based on sentiment, appeal to authority), the next level up being "non-functional arguments" (focusing on conditions that would make capital punishment justified, such as guilt beyond reasonable doubt, if crime is repeated, etc.). The highest (normative) level corresponds to "functional arguments" (e.g., alternatives fail to rehabilitate criminals, deters crime, we have no right to take a life). Clark and Sampson's (2006) evaluation approach is similarly based on establishing an hierarchy of types of argumentation, from levels 0 to 5, beginning from argumentation that is non-oppositional, and ending (level 5) with argumentation involving multiple rebuttals and challenges to grounds.

Whereas approaches emphasising formal argumentation structure centre on the components of arguments themselves, other "functional" approaches situate argumentation in a broader context of dialogue, for example according to whether the dialogue segment has the principal function of resolving a problem, managing the interaction or arguing about the degree of acceptability of alternative solutions (e.g., de Vries et al. 2002). As will be described below, the Rainbow framework is of this type.

Other analysis approaches focus on the different types of reasoning used in argumentation dialogue itself, underlying arguments and counter-arguments. For example, Jimenez-Aleixandre et al. (2000) have analysed claims and warrants in terms of "epistemic operations" such as induction, deduction, definition, analogy and authority.

Finally, the approaches mentioned above centre on the incidence and frequencies of categories of argumentation and of dialogues in which it may be situated. Other analysis methods focus rather on the *relations* between such categories, as they unfold in sequential iterative processes. For example, Leitão (2000) describes at a quite macroscopic level the way in which the social activity of argumentation shapes the cyclic processes of "knowledge building." Beginning with an "argument" (a justified position), once doubts are cast upon it, a second global phase of counter-argument generally occurs, that may introduce a quite different perspective on the debate. In a third phase, the argument and counter-argument already introduced can be treated in several different ways, including the expression of local or partial agreement, and integrative replies that modify the initial argument in some way. To that extent, cycles of argumentation are associated with cycles of negotiation of meaning.

The work of Suthers et al. (Suthers 2006; Suthers et al. 2007) provides a much more micro-level analysis of the collaborative construction of meaning and knowledge, across the semiotic media of typewritten language (CHAT) and shared graphical representations (evidence maps[3]). This approach is based on the unit of analysis of the "contribution" to the collaborative activity, and the concept of "uptake" of such contributions by others. For example, contributions can build on others by creating links between them, by referring to them, or by rewording them. The analysis is concretized in the form of a "dependency graph" between media manipulations (CHAT utterances, manipulations of a diagram) and "conceptions" that are evidenced by them. An aggregation over such a graph provides an analytical vision of the shared meaning that has emerged from the interaction, using specific media resources.

The following five main aspects can be brought out of this brief review of approaches to analysing argumentative interactions in CSCL situations:

The nature of the interactional data to be analysed influences the type of analysis that can be carried out on it. If the analysis is carried out directly on videos of the students' activity, with a view to evaluation of it, then this often leads to the use of quite general categories and a holistic analysis. When the data consists of a text, either as a transcription of verbal data or as a CHAT transcript, then the analyst has the means by which to extensively re-read the data, in a way that is independent of the temporal sequence, and thus apply more microscopic analysis categories.

In CSCL situations, analysis methods will often be required to be applicable across *multiple semiotic representations* (e.g., diagrams, language).

In CSCL research, argumentative activities usually need to be analysed taking into account the *interactive context*, i.e., that of other functional categories of interaction (such as interaction management) and crucially, within the context of processes of elaboration of meaning and knowledge.

[3] From the point of view of the present authors, "evidence maps" can be seen as specific cases of argumentation diagrams, in the domain of scientific reasoning where competing explanations for phenomena such as the disappearance of dinosaurs correspond to claims or theses, and evidence produced in favour or against these claims can take on the roles of (counter-)arguments.

Descriptive analyses can be performed with the objective of identifying components of argumentation structures so that they may be evaluated *normatively*, in terms of the quality or degree of elaboration of argumentation itself.
A distinction can be made between "*static*" analyses, that aim to ascribe codes so that they can be counted and correlated with learning outcomes, and "*dynamic*" analyses, that focus on the relations between contributions to the collaborative activity, and processes of knowledge co-construction. These two approaches are not necessarily mutually contradictory: it is quite possible to perform a "static" analysis of broad functional categories of interaction, so as to identify certain important sequences for more detailed process analysis.

An introduction to the Rainbow framework

We present the Rainbow analytical framework, beginning with its pedagogical motivations, then describing the analytical categories with their theoretical foundations.

The nature, purpose and pedagogical background of the framework

The Rainbow framework was developed as part of a project (SCALE, see above) whose principal aim was to develop internet-based CSCL tools for learning based on argumentative activities, such as writing argumentative texts, constructing argumentation diagrams, and engaging in argumentative interactions, or debates. Rainbow was developed with the aim of analysing the latter type of argumentative activity, *debates*.

As a way of defining precise pedagogical goals of such debates, we elaborated the notion of *broadening and deepening understanding of a space of debate* (see e.g., Baker et al. 2003). A "space of debate" is an abstract epistemological, cognitive and sociological concept: it comprises the set of questions arising, values, epistemological viewpoints (economic, ethical, scientific, etc.), (counter-)arguments, claims and underlying concepts, expressed by a set of social actors, often via mass media, with respect to a societally important question. Examples are the question as to the acceptability of nuclear energy sources, state involvement in education, euthanasia, the objectives of prisons, and so on. Social actors concerned may be various groups of citizens, such as private companies, governmental and non-governmental organisations. In most European countries, national curricula require students to have some knowledge of such "spaces of debate" so that they can become effective adult citizens. The objectives are both that students should have knowledge of such "spaces" and that they should be able to effectively participate in debates on the basis of their knowledge.

Students *broaden* their knowledge of a space of debate when they know a wider variety of (counter-)arguments (in terms of social actors and epistemological viewpoints), important questions arising, and associated value systems, that go beyond their personal views. They *deepen* their knowledge when they are able to go beyond enumerating arguments at a shallow level, in arguing on arguments, and in negotiating the meaning of important underlying concepts (e.g., in the debate on cloning, the concept of what is "natural" or not is important).

The primary aim of Rainbow, therefore, was to enable identification of phases of debate in which students broadened and deepened their understanding. A secondary aim was to enable analyses of students' debates to inform redesign of CSCL tools. For example, how much of the students' time was spend on managing their interaction? Several experiments

were carried out with the CSCL tools, in four different European countries (Finland, France, Netherlands and the United Kingdom), each of which involved the comparison of use of different tools, for example CHAT and an argument diagram tool. Rainbow was thus designed to be used for different types of semiotic interactions, and as a means of identifying characteristics of those interactions (notably, the extent to which the students had "broadened and deepened") to be correlated with pre–post test differences.

In sum, the purpose and nature of Rainbow can be characterised in terms of the distinctions made in the above review of interaction analysis approaches:

The nature of the interactional data to be analysed. Rainbow was developed to apply to automatically recorded traces of computer-mediated interactions, involving keyboard and mouse input (i.e., not video). This means that the corpus is relatively restricted in length (in comparison with transcriptions of spoken interactions, it does not contain paraverbal aspects such as intonation (although, of course these can be 'transferred' to CHAT by, for example, 'shouting' in capitals), and sequentiality of utterances may be different from spoken interactions (e.g., no overlapping). The analyst can review the corpus from the beginning to the end, look back, and so on.

Multiple semiotic representations (diagrams, language). The framework was designed to apply to both CHAT and argumentation-diagram mediated interactions. In some cases, the students' interaction is distributed across both media.

Interactive context. Rainbow situates the analytical category corresponding to the principal educational goal of the students' debates ("broadening and deepening") in the interactive context argumentation and expression of opinion, as well as in that of diverse forms of interaction management and social talk. "Broadening and deepening" is seen here as a specific type of elaboration of meaning and knowledge relating to argumentation.

Descriptive vs. normative. Rainbow is descriptive, in that it identifies frequencies of functional categories of interaction. This could however facilitate normative evaluation, since it identifies precisely the (argumentative) sequences to be evaluated.

Static ("code and count") vs. dynamic process analysis. Rainbow is a framework for ascribing unique functional codes to unique segments of the interaction, in a "code and count" approach. As we discuss subsequently, this does not mean, however, that categories are assigned outside their interactive contexts. Again, such an analysis can help to identify specific sequences that merit a more detailed dynamic process analysis.

Example task situation analysed

In what follows, Rainbow will be presented with detailed examples of analyses from a specific interaction corpus (collected in Lyon, France[4] in 2002). Students (16–17 years old) were asked to debate the question "Should the production of Genetically-Modified Organisms [GMOs] be allowed or not?". At the time the corpus was collected, this question was greatly debated in media in France (given the importance of agricultural production in that country). In the French national curriculum, this topic is to be dealt with in Life and Earth Sciences and also in Citizenship Skills. Students worked on local network computers in their school, in dyads, separated in different but adjacent computer rooms. One class (of 30 students) debated only using a CHAT system; a second class of a similar size used an

[4] All extracts have been translated by the authors from the original French, preserving or transliterating the students' level of informality of language, typing and grammatical mistakes and abbreviated style.

argument diagram tool (DREW: http://drew.emse.fr—see Fig. 5, below) for debating, together with a CHAT.

The students' work followed four successive phases. In the first phase,[5] the students read a text (around 15 pages) written in collaboration between the researchers and a group of four teachers, which presented the space of debate concerning GMOs in a way that was carefully balanced with respect to numbers of *pro* and *contra* arguments, social actors (the science ministry, non-governmental organisations, citizens' debates on Internet forums, and private GMO producing companies) and epistemological viewpoints (scientific, economic, medical, ethical). Students were given a table structured on the same principles (see "Topical Analysis" below), in which to make notes on principal arguments. In the second phase, students were asked to write a short text (around half a page), termed a "pre-text," arguing their personal point of view on the question. In the third phase, they debated the question (for maximum one hour), and in the fourth, they were asked to revise their pre-texts "in the light of the debate" ("post-texts").

The students' debates reflect this task sequence in several ways. In the first phase, students often express the arguments that they had identified in their tables and written in their pre-texts in an almost list-like manner. Once some—but by no means all—of these arguments had been discussed, they then often moved on to discussing more deep-seated personal views. Secondly, the students knew that they would subsequently have to revise their texts (they were informed about the whole task sequence at the outset), and so perhaps paid specific attention to memorisation of others' arguments. Thirdly, the tasks were carried out in the school itself, under their teacher's supervision, who would subsequently mark their work: there was therefore something at stake for the students. Results of this work are discussed in the subsequent section on validation of the Rainbow framework.

The following examples of the corpus are intended to illustrate the Rainbow framework, and are taken exclusively from the CHAT debates, for ease of exposition. Analysis of debates that were carried out via the argumentation diagram tool is also discussed in a subsequent section, devoted to extensions of the framework.

General theoretical and methodological background

As stated above, the principal aim of Rainbow is to identify the extent to which students engaged in computer-mediated interactions engage in the types of argumentative activities that lead to a specific type of knowledge elaboration: broadening and deepening understanding of the space of debate. But such activities need to be understood in the broader framework of social and task-focused interaction. Rainbow therefore draws on and synthesises a wide variety of theoretical approaches to the analysis of *dialogue*, *argumentation dialogue* in particular, and *knowledge elaboration processes*, the specific details of which will be presented below, alongside the attendant analysis category definitions. The concrete analysis categories that are actually applied to interaction data are based on a few basic theoretical distinctions (represented in the form of a decision tree, whose leaves are the categories).

The first of these fundamental distinctions is between activity that is "inside" what is *prescribed* by the teachers–researchers and which is "outside" it. For example, if the teacher asks the students to work in groups to solve a particular arithmetic problem, with the goal that they should understand the meaning of the arithmetical operation "÷", then all activities that are concerned with social interaction relating to collaboration in solving this problem,

[5] A phase "zero" preceded this, in which students were given training in use of the Internet tools and on basic principles of argumentation: differences between theses, arguments and opinions.

and directed towards achieving that pedagogical goal, are "inside" the activity (otherwise, they are "outside" it: for example, discussing what to eat at lunchtime). As we shall see, this distinction can be difficult to make. Our approach draws on the concepts of "interactive space" and "encounter," as defined by the linguist R. Vion (1992).

We make a second fundamental distinction, within "inside" activity, between that which is focused on the "task" (cf. the seminal work of Grosz 1981) or "problem" (e.g., producing mathematical solutions; manipulating an engine in order to repair it) and which is focused on different aspects of *managing collaboration* in achieving that task. In the latter sub-category (non-task-focused), we restrict our analysis to two main aspects: predominantly social talk, and types of interaction management (Bunt 1989).

By such a process of elimination, we arrive at the *task-focused* part of the interaction. In many task-focused dialogues, language-based interaction is a means of regulating the realisation of a task that is 'external' to that interaction: for example, people trying to put up a tent together (external task) will often speak together in order to coordinate actions, and to achieve grounding (Clark and Schaefer 1989) on certain points (e.g., "what do you mean by the inner tarpaulin?"). But the type of task that Rainbow was designed to analyse—i.e., *debate*, or *argumentative interaction*—is 'internal' to the dialogue itself: the dialogue (for example, when it takes the form of an exchange of typewritten CHAT messages) is both the medium in which the task is realised (by verbal expression of argumentative moves) and the medium in which this cooperative task is regulated. In other terms, dialogue is the means for realising a *dialogical task*.

Our principal theoretical approach for analysing argumentation dialogue is the dialogic logic of Barth and Krabbe (1982), which has been adapted and extended for analysis of real human dialogues (e.g., Baker 1999, 2003). This approach sees argumentation as a means of resolving "conflicts of avowed opinions," by the regulated use of certain dialectical moves. Our principal argumentation categories are thus "opinions" (initial, at the outcome of debate) and, quite simply "argumentation" (theses, counter-arguments, arguments, concessions). Purely logical approaches restrict what counts as an argument to logical relations (for example, "p" is an argument that defends "p ∨ q"). Since this is clearly too restricted for analysing real argumentation between human beings, we adopt Toulmin's (1958) notions of warrants and backing, as means for expressing the nature of the argumentative link.

Our final task-oriented category, "broaden and deepen," corresponds to the knowledge elaboration processes that are specifically linked to argumentative activity. In this case, the precise operational definition that we describe below draws on a wide variety of work in argumentation theory (e.g., Perelman and Olbrechts-Tyteca 1958; Walton 1989), and on work on argumentation and co-construction of knowledge (Baker 1999; Leitão 2000).

Whilst these theoretical approaches are at the origin of the definitions of the analytical categories themselves, their application to corpora analysis requires certain theoretical simplifications, on methodological grounds, as we discuss below. For example, utterances in dialogue are inherently *multifunctional*: an argument can at the same time be a criticism of an idea and a person, introduce a new theme and propose a new interpretation. Since Rainbow is partly designed for a "code and count" approach, the analyst is required to make the difficult choice of a single 'dominant' function for a single dialogue segment.

The rainbow analysis categories

The Rainbow analysis categories are presented in Fig. 1, grouped together in an hierarchical tree.

Brief definitions of the above analysis categories are shown in Table 1.

Below, we will discuss these seven categories starting at the top of the hierarchical tree, providing illustrative examples of interactions and their analyses.

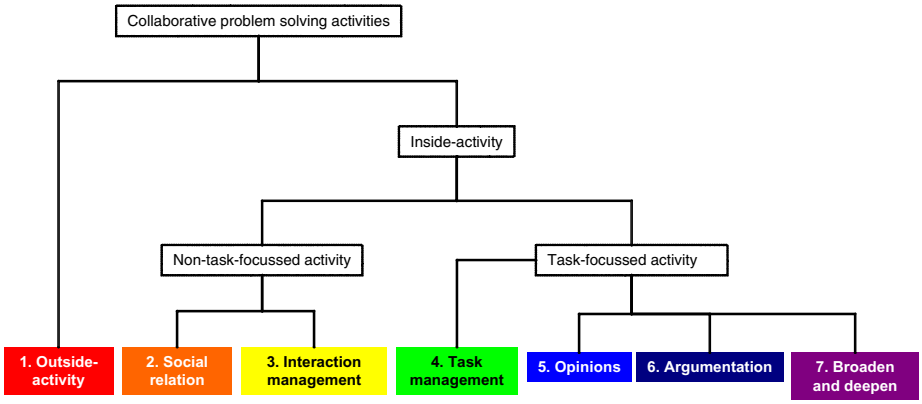

Fig. 1 Rainbow analysis categories

Collaborative activity: Inside and outside

The distinction between category 1 and all other categories taken together is determined from the point of view of the research/teacher, who defines and asks the students to carry out a particular collaborative activity, such as "debate about nuclear power using the CHAT tool." Of course, the students may carry out some other activity (e.g., discussing what film to see in the evening; the homework that has to be done, etc.), and they will necessarily understand the researcher-imposed activity in their own way. If the students' activity falls within the interaction imposed by the researcher, then it is in the "inside-activity" part of the tree, otherwise, it is "1. outside-activity."

Table 1 Brief definitions of Rainbow analysis categories

Rainbow category	Brief definition
1. Outside activity	Any interaction that is not concerned with interacting in order to carry out the teacher/researcher-defined task, including socio-relational interaction that does not relate to interacting in order to achieve the task, e.g., talk about last night's party.
2. Social relation	Interaction that is concerned with managing the students' social relations with respect to the task (debating about X), e.g. greeting, leave-taking, politeness, expressions of frustration with the way the partner is interacting, etc.
3. Interaction management	Interaction concerned with managing the interaction itself: who will speak or not and when (coordination), establishing contact, perception, understanding, attitudes (communication management), topic shifting, time management, ...
4. Task management	Management of the progression of the task itself: planning what is to be discussed, establishing whether problem solved or not, ...
5. Opinions	Interaction concerned with expressing (stating, requesting) opinions (beliefs, acceptances, ...) with respect to the topic debated, especially (but not only) at opening and closing of sequences of argumentative discussion (dialectical outcomes).
6. Argumentation	Expression of (counter-)arguments directly related to a thesis (e.g. GMOs increase famine because farmers become dependant on seed companies), theses themselves, requests for justification
7. Broaden and deepen	Interaction concerned with (counter-)arguments linked to (counter-)arguments, argumentative relations, and meaning of arguments themselves (elaboration of them, definition, extension, contraction, i.e. any discursive or conceptual operation performed on content of arguments themselves).

This distinction draws on Vion's (1992) notion of an *interactive space* in an *encounter*. Strictly speaking, we should say that once students are connected together by a CSCL system, all of their activity in interaction constitutes an encounter (or a social encounter). Within that encounter, there can be different interactive spaces. In simple terms, an interactive space is associated with a specific theme or goal. Consider the example of an encounter, in a specific time and place, between a doctor and a patient. One interactive space (the principal one) could concern the patient's illness and how it is to be treated. During the encounter, interaction in this space could take place in a way that alternates with another, within which the doctor and the patient—who happen to be both members of the same sports club—discuss their sporting prowess.

The distinction can be fuzzy—when does discussion on a different theme constitute another interactive space, how far away can the theme be?—but in principle it can be drawn. For example, suppose the patient talks about her back pain (the "medical consultation" interactive space), and the doctor introduces the theme "sport." This would not be sufficient for identifying a shift to a different "friends in leisure pursuits" interactive space, since the doctor could be attempting to determine the cause of the back pain in sporting activities. This example illustrates an important methodological issue that will be discussed later in the paper, concerning *contextuality* of analysis: units of analysis cannot be analysed individually or independently from interactive context. And in order for the analyst to understand the main goal or intention associated with utterances, it is usually necessary to look forward to determine how utterances were jointly understood by the interlocutors.

Although the "1. Outside activity" category can be seen as defined essentially in negative terms (what the activity is *not* about), a deeper understanding of this distinction requires understanding what "inside activity" is. This will become apparent once the other six categories have been discussed. But for the present, it can be said that being "inside" the activity, in the specific case of a knowledge-based debate, means both debating on and around the topic and managing different aspects of the debate.

The case of "social talk" (see below) provides a good illustration of the difficulty involved in making the inside/outside analytical distinction in a contextual way. Suppose that one student, at a specific point in the interaction, types "I'm tired":; is this inside or outside the activity of debating a specific topic? How is "I'm tired" to be interpreted? At first sight this looks clearly like "outside activity"; but providing a more adequate analysis depends on taking into account where the utterance occurs in the interaction. Suppose that "I'm tired" occurs as the second message in the whole interaction, following "Hi, how are you?". Since "Hi, how are you?" is part of the social ritual of opening an interaction (an aspect of interaction management, category 3), then "I'm tired," reacting to this, is also part of that ritual. So it would be analysed as inside the activity. Suppose, alternatively, that "I'm tired" occurs in the middle of an extended debating sequence, then it could be interpreted as an attempt to move out of that interactive space, i.e., as outside activity.

Extract 1, below (Table 2), provides further illustration of the difficulties involving in making the inside/outside analytical distinction.[6]

In the above, lines 86, 87 and 88 are categorised as "1. Outside activity" for two reasons. Firstly, and at first sight, it is difficult to see how Carla's and Betty's physiological states relate directly to carrying out interaction in order to achieve the researcher's imposed task (debate about GMOs). Secondly, these lines are flanked (lines 85 and 89) by arguments, relating to the debating interactive space, so this can be interpreted as an insertion of a different space.

[6] In all such examples shown here, the columns are as follows: column 1=line number from the beginning of the interaction; column 2=time, Hh:mm:ss, from the opening of the CHAT session: column 3=participant name; column 4=written CHAT messages; column 5=rainbow analysis categories.

Table 2 Extract 1

N	Hh:mm:ss	Loc	CHAT	Rainbow
85	10:04:09	Betty	the synthesis is that you are for and i'm against	
86	10:04:27	Carla	(my throat hurts)	1. Outside activity
87	10:04:36	Betty	are you sick?	1. Outside activity
88	10:05:02	Betty	i wanna sleep!!	1. Outside activity
89	10:05:15	Carla	you'll see you day that this system is put into work all the benefits that it will bring	
90	10:06:07	Carla	did you know that the prof is going to read our discussion john ? just told me	
91	10:06:12	Betty	No I'm not as sure as you and for the moment most everybody is against so its not going to happen right away	

Line 90 is more problematic. Although it is also flanked by argumentative moves (and could therefore be seen as part of an outside-activity space), it seems to have something to do with the debating task itself, since it concerns the broader pedagogical situation within which it is carried out (the debate will be marked by the teacher). There is no absolute answer to this question; and yet the fact that it can be raised reveals the importance of defining precisely what is and what is not part of "the collaborative activity" to be carried out.

Task focused and non-task focused activity

In the cases we are considering here, debating a particular topic (such as the justness of a specific electoral system) is considered to be 'the task.' This is a very specific form of task since it is both expressed in and to be achieved in verbal, language-based[7] interaction. To that extent it is different from physical tasks—such as repairing heating systems—or even most school like problems—that may require writing answers and calculations on paper—where verbal interaction is a means to coordinate and understand problem-solving that is in some sense 'outside' the interaction. We could say that debating is a cognitive-linguistic task, which is *internal* to the interaction itself. Even though the questions to be debated may arise in 'the world' outside the debate itself, the debate is a means of elaborating possible solutions, but not of actually implementing them.

So debate takes place in communicative interactions, such interactions need to be managed, on several levels. Therefore, debating itself is seen here as "task focused" (to be detailed below) and managing the interaction within which this task is achieved is viewed as "non-task focused."

Non-task focused interaction (inside the collaborative activity)

We identify two main categories here: "2. Social relation," and "3. Interaction management."

Since the interaction takes place between human beings, it is necessarily a social interaction that can/will not be carried out unless a 'working' interpersonal relationship is maintained (van

[7] We use the term "language" here in its broadest sense, to include the use of any system of signs, including non-verbal ones, and non-linguistic ones (such as symbols, diagrams).

Table 3 Extract 2

N	Hh:mm:ss	Loc	CHAT	Rainbow	Subcategory
10	09:34:22	Betty	hi	3. Interaction management	Communication management/contact
11	09:34:32	Carla	hiya	3. Interaction management	Communication management/contact
12	09:34:39	Betty	how's it goin?	2. Social relation	Politeness
13	09:34:53	Carla	good and you?	2. Social relation	Politeness
14	09:35:05	Betty	ok, so what about GMOs?	4. Task management	Opening debate task on general topic "GMOs"
15	09:35:19	Carla	and you?	3. Interaction management	Communication management/coordination
16	09:35:26	Betty	no, you first	3. Interaction management	Communication management/coordination
17	09:35:42	Carla	you little rascal	2. Social relation	Playful joking

der Puil et al. 2004). In this category, we put all utterances that are clearly concerned with affect (expressing pleasure, frustration, anger) *in relation to the* (debating) *task*,[8] with establishing (un)friendliness (joking and so on), but also certain ritualized aspects of opening and closing interactions (see below). As we discuss in a subsequent section, under the title "multifunctionality," clearly all cognitive interaction between people also has a "social relation" dimension (Perret-Clermont et al. 1991). In many cases, therefore, ascribing the category 2 involves deciding that the socio-relational dimension is *dominant*.

The notion of interaction management in Rainbow is principally derived from the work of Bunt (1989, 1995), who distinguishes task focused communicative acts (such as requests for information) from "dialogue control" acts, whose function is to keep the dialogue on track. The principle types of interaction management are as follows:

> *coordination*: interaction about who will communicate or not, and in what way (e.g., "you say something," "over to you," "stop interrupting me," etc.). Interaction about coordination simply concerns mutually agreed use of the communication channel;
> *communication management*: according to Allwood et al. (1991), this includes checking contact ("are you still there?"), perception of utterances ("did you hear me?," "did you read that?"), understanding ("do you see what I mean?"; cf. the theory of "grounding" of Clark and Schaefer 1989) and attitudes in reaction ("Ok," "I don't agree");[9] it can also include own communication management (e.g., "Hang on, what I meant to say was ..."));
> *dialogue structuring*: opening, closing, topic shifting, re-opening ...;
> *time management*: "wait a minute," "hurry up, we've got to finish," etc.

Extract 2 (Table 3) illustrates some types of interaction management and social relation communicative acts.

[8] If, for example, a student expresses anger, etc., about something that is nothing to do with the task, then this would be "1. Outside activity."

[9] Note that attitudes-in-reaction in this case is not to be confused with category "5. Opinions," which concerns exclusively the students' opinions about what is being debated. Attitudes in reaction in the Interaction management category could, for example, include saying "OK" to a proposal to say something, outside the argumentation itself.

In the above extract (2):

> Lines 10 and 11 are Interaction Management, of the subtype "Communication Management/Contact": the students establish that they are in contact with each other (this being especially important across Internet), there, and ready to interact.
> Lines 12 and 13 concern conventional expressions of politeness—social relation—at the beginning of any social interaction.
> Lines 15 and 16 are Interaction Management, of the subtype "Coordination": who will speak first about the GMO topic? At first glance, line 15 could also be interpreted as 2. Social relation. Carla could be repeating her question of "how are you?" to Betty. But since Betty interprets Carla's "and you?" to mean what do you think about GMOs" by saying "no, you first," as analysts, we must also interpret it in that way.
> Line 17 is clearly socio-relational; in the context of the interaction it can be seen as reacting to Betty's refusal to "go first," and is thus internal to the interaction. But this is debatable: it could also be seen as 1. Outside activity (or even 3. Interaction management, since it responds to line 16). We prefer the former analysis, the criteria being that this is socio-relational talk relating to interaction management, which is internal to the interaction, and so, therefore, is this particular example of social talk.

It is clear that in computer-mediated interactions, the proportion and nature of interaction management is especially important, since it can give some indication of the possible difficulties that the students are having in appropriating the software tools.

Task-focused interaction: Argumentation related categories

With respect to argumentation itself, we adopt a broadly pragma-dialectic approach, the foundations of which are to be found in the work of Barth and Krabbe (1982) and Van Eemeren and Grootendorst (1984). Given that this approach is largely normative and/or logical, we amend it in several respects, in order to describe real complex dialogues produced by people.

According to this approach, argumentation is fundamentally a type of *dialogue*, and a type of dialogue *game*, to be won or lost. The game is played by protagonists–proponent, opponent or neutral—with respect to one or more theses. By analogy with a game such as chess, the 'pieces' are speech acts, expressing statements. The 'moves' are various types of attacks and defences, together with concessions and–extending the model–requests for such moves (such as requests for defences). The game is governed by a set of ground rules that state what moves may or must (i.e., without flouting the rules) be made (or not) at a given state of play. For example, one rule states that when a statement is attacked, that attack must be followed by a defence (or else the player who does not or cannot do this, loses the game). Similarly, self-contradiction—in a pragmatic sense of both attacking and defending a statement in a given argumentation sequence—entails losing the game. The point of these rules is to ensure that the debate converges to a determinate outcome.

Although these rules are a priori and normative, there is some evidence that they correspond to the way in which people actually carry out and evaluate debates (e.g., Trognon 1990). It is, however, necessary to relax certain dialectical rules, given that real life argumentation often goes beyond purely adversarial debates (see Walton 1989 for a typology), to include so-called forensic debates, the aim of which is to cooperatively search for the intersubjective 'truth' concerning a question, by examining arguments for and against competing hypotheses. In this latter case, it is quite acceptable for a given protagonist to argue both for and against certain statements. Moreover, learning about the

space of debate, for which the Rainbow framework was developed, requires exploration of the debate space, instead of playing a purely adversarial game.

The details of specific argumentative moves and rules do not entirely concern us here, given that in Rainbow, all that is required is to be able to categorise certain utterances as argumentation or not. Specific analytical criteria for so doing will be discussed below. What we retain here are the general principles of pragma-dialectical models—types of dialogue games, played according to implicit ground rules—and the theoretical terms that they encompass (dialectical roles, moves; theses).

In general, the opening of an argumentative *sequence* can be identified in terms of a ternary exchange structure (see Baker 1999, for precise details) that can take one of the two following forms:

Ternary structure 1:

- Move 1: X expresses a claim (e.g., "GMOs should be authorised")
- Move 2: Y attacks the claim of move 1 (e.g., "They will destroy the environment!")
- Move 3: X defends claim against attack (e.g., "No one knows that!")

Ternary structure 2:

- Move 1: X defends a previously stated claim (e.g., "GMOs will eliminate famine!")
- Move 2: Y attacks either the claim or else the defence (e.g., "No, poor people do not have money to buy them!," or "GMOs destroy nature")
- Move 3: X defends the defence or claim against attack (e.g., "Look at the increased corn yields in ...," or "GMOs can produce new vaccinations")

What is in common across these structures is that both pro and contra arguments have been expressed, revealing different points of view on the acceptability of a claim, and the initial adoption of *dialectical roles* (proponent, opponent). A single protagonist could also express such different roles.

The closing of an argumentative sequence is identified once there is concession ("Ok, I agree"), explicit discussion of the argumentative outcome ("Ok, 1 all round," "So you must be wrong about that") or by shift of topic to a new issue to be debated.

Task management

We stated above that an argumentative interaction, or debate, is a special type of task, whose goal is internal to the dialogue itself. The task is basically to come to a joint decision (including agreeing to disagree, and not succeeding in that task) about what should be accepted in relation to a question, by means of expressing and evaluating arguments with respect to it.

Like all problem-solving tasks, debating has to be managed. Here, this includes two main aspects. Firstly, managing opening, closing, re-opening and shifting *topics*, which correspond on the most general level to the *theses* being debated. Secondly, it includes checking that the ground rules of debate, referred to above, are respected. This is not always expressed formally; but the checking of such rules can be seen in expressions such as "we're not getting anywhere," or "that's all you keep saying." Extract 3 (Table 4), provides an illustrative example of category 4. Task management.

In the above (Table 4), line 63 follows a long sequence in which arguments against GMOs were expressed. When Astrid intervenes in line 64, she in fact attempts to manage the debate task by shifting it to the *pro* argumentation side. And when Carol, in line 69,

Table 4 Extract 3

N	Hh:mm:ss	Loc	CHAT	Rainbow
63	09:54:45	Carol	also, their fields risk being contaminated by neighbouring GMO fields	
64	09:54:56	Astrid	there aren't only negative points about GMOs	4. Task management
65	09:55:04	Barbara	yeah, i really agree really with you caro	
66	09:55:53	Astrid	me too	
67	09:56:28	Carol	er no there are positive points like medical research to find medicine made with GMOs to fight against cancer	
68	09:56:42	Barbara	no of course but for every positive aspect, like finding vaccinations, there's 1 negative aspect like problems with some foods	
69	09:57:40	Carol	If you carry on like that barbara we're never going to get anywhere	4. Task management

criticises Barbara's attempted synthesis of pro and *contra* argumentation, she can be seen as refusing that the debate task pursues that "*pro* vs. *contra*" direction: she wants it to continue by enumeration of the positive points.

Argumentation itself: Argument and opinion

There are two crucial analytical questions on argumentation here. The first one concerns the distinction between argument and opinion. The second one concerns the identification of argumentation itself, together with its object (the statement towards which it is directed). We will discuss these questions below.

Opinion

It seems that it is possible to express an opinion (acceptance, belief, concession, doubt, certainty, etc., or negative variants of them) without expressing an argument at the same time (for example, by stating simply "I agree," or "I'm against it"), whilst the expression of (counter-)argument seems to 'carry with it' an implicit opinion. On the latter point, it might be thought that someone who states an argument against GMOs, such as "we cannot control their dispersion in the biosphere," or else an argument in favour of them, such as "they can help to create new medicines," thereby expresses positive and negative opinions, respectively, about GMOs. We reject this view for two reasons.

Firstly, on methodological grounds, it is preferable to give precedence to what is expressed explicitly—an argument—rather than to the implicit (putatively here, an opinion). So in the just mentioned examples, the analysis would be "6. Argumentation," rather than "5. Opinion."

Secondly, on theoretical grounds, argumentation is primarily concerned with what is publicly stated, rather than what is thought (Barth and Krabbe 1982, and the principle of "externalisation" in formal dialectics). What is said is said and cannot be unsaid, even if it can be retracted. And people can be held to account for what they have said. With respect to what people purportedly thought, it is always possible for them to deny it; so

argumentation, although finding its motivation in personal opinions, cannot function primarily with respect to them (although it can effect changes in them, in rhetorical terms).

Thirdly, it is simply not true that in all human debates, arguments express implicit opinions. In an adversarial debate, where it is established that opinions are firmly opposed, then of course everything stated by the proponent and by the opponent will be interpreted as a function of pro and contra opinions, respectively. But in cooperative debates, participants can simply 'evoke' arguments, not necessarily implying commitments, as possible contributions to the joint activity, that could be glossed as "this is a possible argument to be taken into account (although I don't necessarily subscribe to it)." This is what is commonly known as hypothetical argument, or playing the devil's advocate. In an educational debate, argumentation may be analysed as a specific case of collaborative problem-solving, whose goal is rather to share cognitions (evaluations and propositions) than to maintain a dialectical role (proponent or opponent) throughout the interaction (Quignard 2000, 2005).

What we term "opinions" here is thus quite a heterogeneous class, including belief and acceptance (Cohen 1992), commitment, concession, various degrees of certainty, and their negative correlates.

Such opinions can be expressed in a variety of dialogical contexts, including:

at the opening of the debate—expression of general opinions with respect to the principal thesis ("I'm against," I'm for it," etc.) that can be seen as part of adoption of dialectical roles;
during debate—more local opinions with respect to arguments and argumentative links;
at the outcome of the debate—expression of possible changes in opinion, such as concession of a thesis that was initially rejected.

Argument

In terms of classical logics, an argument is a premise (p) from which a conclusion (q) can be deduced, using a conditional proposition ($p \rightarrow q$) and an inference rule (*modus ponens*); and similarly with respect to counter-arguments (with *modus tollens*). But human reasoning in dialogue is not always of this kind. In Toulmin's (1958) famous model, the inference rule becomes a more general argumentative link, with underlying "warrants" or "backings" that authorise the transition from datum to conclusion.

In order to take account of the variety of human dialogical reasoning, we shall adopt an even broader view of argument (Baker 2003), that recognises the different ways in which statements can be linked together (argument is fundamentally a relation between statements) and influence each other. A statement α is an argument for another statement β (which when thus argued takes on a special name, "thesis") when, from the point of view of a dialogue participant:

(1) an increase in the degree of acceptability of α increases the degree of acceptability of β;
(2) it is possible for the participant to give an account, justification, explanation of 1 (i.e., to make the argumentative link explicit);
(3) As manifested by the dialogue itself, the participants interpret the utterance as an argument[10] (for example, they express disagreement with it, they contest its argumentative relevance, they counter it, and so on).

[10] This issue, relating to the object of analysis and the negotiation of meaning, will be discussed in the next main section of this paper.

Counter-arguments work in a similar way, with the exception that an increase in the acceptability of the argument *decreases* (subjectively, rather than 'really') the acceptability of the thesis. Of course, β can correspond to any theoretical object of argumentation: it can be an isolated statement, a thesis, another (counter-)argument, or an argumentative link.

The following are hypothetical examples, by way of illustration (real corpus examples will be discussed below); "↑" means increase in acceptability, "↓" means decrease in acceptability, "r(α,β)" is the argumentative relation:

(a) α↑:it rained today; β↑: it will rain tomorrow; r(α,β): inductive argument;
(b) α↑:it rained today; β↓: it will rain tomorrow; r(α,β): counter-inductive counter-argument;
(c) α↑: you cannot trust all people all the time to act for the right reasons; β↑: euthanasia should be forbidden; r(α,β): argument from possible unacceptable consequences (euthanasia could take place without consent of the person whose life is taken);
(d) α↑: you are not against body piercing, and that is not natural; β↓: I am against human cloning because it is not natural; r(α,β): indirect attack, by counter example, on the implicit generalisation "I am against everything that is not natural";
(e) α↑: throughout history, no army has been able to occupy a country for a long time without some degree of consent of the people; β↑: that occupying force will have to pull out from that country shortly; r(α,β): argument from generalisation across cases.

In the above examples, it is clear that the nature of the argumentative link is crucial (cf. the previous discussion of Jimenez-Aleixandre et al. 2000), since it can be interpreted as for or against the thesis. A variety of types of reasoning underlying these links can also be seen, together with the fact that an argument does not always apply 'directly' to what is stated, but often to some type of operation that is applied to it, such as generalisation.

Suppose that we are analysing a statement in a dialogue that appears, intuitively, to be an argument, then it can be problematic to identify its object, i.e., the statement with respect to which it is an argument. In a sense, all (counter-)arguments have implications for the general thesis being discussed. However, it is probably more precise, in analytical terms, to identify the objects of arguments that are the most recent in the dialogue, based on thematic links.

Many of these points are illustrated by discussion of extract 4[11] (Table 5), below. We restrict ourselves at this point to analysis of argumentation and opinions, using the CHAT message as a principle of segmentation (a discussion on segmentation as well as a more fine-grained segmentation and analysis of this same extract will be presented further on in the paper).

It is important to note that some of the utterances that we analyse at this point as *arguments* will be subsequently re-classified as category 7. Broaden and deepen, given that one manifestation of this discursive activity (Table 5) involves expressing arguments about arguments.

If we look through the segments marked "5. Opinions" in the above extract, two points can be made. Firstly, most of the opinions are not expressed spontaneously by the speaker, but rather as answers to questions about what opinions are. Secondly,—and relatedly—the expression of requested opinions is often intermingled with communication management, on the level of assuring mutual understanding. In other terms, the students are concerned to clarify what their opinions genuinely are at this stage of the debate, in relation to the arguments that are expressed.

[11] In this extract, as with others, we have transliterated the students' own typing and/or orthographic mistakes (e.g., "anmals" for "animals") from the original French.

Table 5 Extract 4

N	Hh:mm:ss	Loc	CHAT	Rainbow
24	09:50:03	Anne	Let's talk about GMOs	
25	09:51:06	Anne	and you, do you think there are any risks?	5. Opinions
26	09:52:24	Béatrice	there's not only foods that will be affected, anmals won't be (whether in taste or quality) what they used to be before	6. Argumentation
26	09:52:24	Béatrice	animals	
27	09:53:44	Béatrice	of course there are risks even in the domain of health, with the appearance of new viruses, for exmple	6. Argumentation
28	09:55:52	Anne	yes but there are also lots of medicines that are going to be produced thanks to GMOs and that won't help anything. Don't you think so?	6. Argumentation
29	09:57:55	Béatrice	yes itss true but even in the domain of research things move forward; they discover new vaccinations and others become inefficient	6. Argumentation
30	09:58:03	Anne	I think that new bacteria will appear because of GMOs and that antibiotics won't be able to destroy them any more	6. Argumentation
31	09:58:22	Anne	I think that new bacteria will appear because of GMOs and that antibiotics won't be able to destroy them any more	
32	10:00:08	Béatrice	if I understand you rightly you're against; but what do you think about ethical problems raised by GMOs	5. Opinions
33	10:02:04	Anne	I think that if we keep going against the laws of nature it will turn back against human beings	6. Argumentation
34	10:02:35	Anne	Arre you for or against?	5. Opinions
35	10:03:50	Béatrice	Didn't you understand tht I'm for	5. Opinions
36	10:04:03	Anne	no against sorry	5. Opinions
37	10:04:37	Anne	right, now we'd better sum up so what do you propose	

Anne thought that Béatrice was against GMOs, whereas she states that she is "for" them; and Béatrice understands that Anne is against them. This uncertainty can be explained as a function of the arguments that the students actually express (see below): since Béatrice expresses three arguments *against* GMOs, and one in favour of them, it is understandable that Anne does not understand why Béatrice is "for" them.

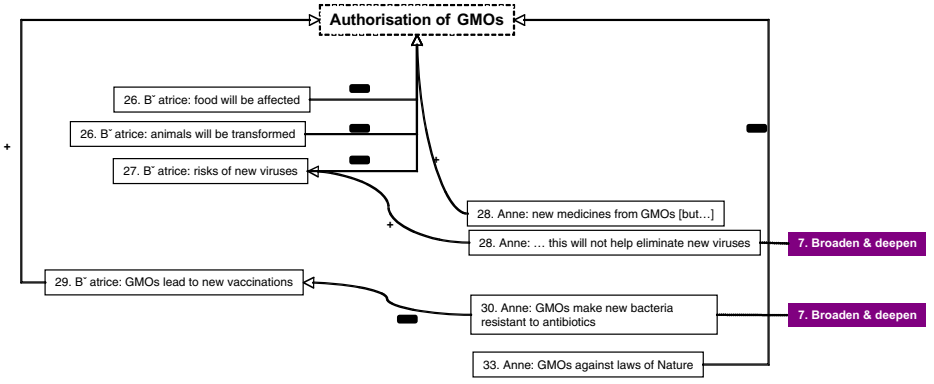

Fig. 2 Graphical analysis of arguments expressed in extract 4

The arguments themselves can most clearly be represented in the form of the diagram below (Fig. 2), where boxes represent statements (including the principal thesis discussed) and "+" and "−" on arrows represent argument and counter-argument links, respectively.

Béatrice firstly expresses two counter-arguments against the authorisation of GMOs. One possible analysis would be that in both cases, the argumentative link depends on the following assumption (warrants): food, including animals, will be negatively affected. In that case, increased acceptance of a possible negative consequence decreases acceptability of the cause of that consequence, i.e., authorisation of GMOs. A similar analysis applies to her counterargument about new viruses being created (by GMOs), since a priori, new viruses are not good things. She finally produces one argument in favour of GMOs: they can help create new vaccinations (these being assumed to be positive for health).

Turning to Anne, her first positive argument is that GMOs produce new medicines; the positive argumentative link depends on the backing that medicine is generally a good thing. She also supports (line 28), or rather conceded, Béatrice's counter-argument (new medicines will not stop new viruses emerging). In line 30, she criticises Béatrice's positive argument about new vaccinations, by saying that they will not necessarily help, since new bacteria will be resistant to them, although she makes the common mistake of confusing bacteria and viruses.[12] Thus in two cases, Anne's argumentation is reactive with respect to that of Béatrice: she produces arguments on arguments, that—as we discuss below—correspond to a specific type of "deepening" (category 7) the debate. Finally, Anne produces a new counter-argument: GMOs are against Nature. In a sense, this idea was implicit in Béatrice's initial counter-arguments: when animals are "not what they used to be," this can be seen as "unnatural."

Broadening and deepening the question debated

In a debate, students cannot only share, or bilaterally acquire from their partners, arguments that they had not previously thought of, but they can also clarify their understanding of the very questions being debated, together with important underlying notions (such as "Nature," "gene" and "modification"). This phenomenon has been extensively described in argumentation research. For example, Walton (1989) has described how, in an everyday conversation about the advisability of obligatory tipping in American restaurants, this topic 'deepens' to a discussion about a more fundamental issue, that of the role of the state in regulating commercial affairs. Debate can also lead to new associations or dissociations of concepts (e.g., Baker 2002; Perelman and Olbrechts-Tyteca 1958). More generally, Naess (1966) has proposed that the function of argumentative interaction is not so much to win a dialogue game, to exchange arguments, but rather to make the participants understanding of the very thesis that is being debated more precise.

Category 7. "Broaden and deepen" is crucial to the Rainbow framework, since its incidence corresponds to the extent to which a fundamental pedagogical goal has been attained by the students, i.e., exploring the space of the debate (knowing more and more varied arguments) and deepening the space of debate (conceptually and argumentatively). But such aspects are notoriously difficult to analyse. For this reason, we have proposed a specific, somewhat simplified, yet analytically operational definition of this category, schematised in Fig. 3 below.

Figure 4 shows a possible instantiation of the general schema shown in Fig. 3.

[12] Our aim is descriptive, not evaluative.

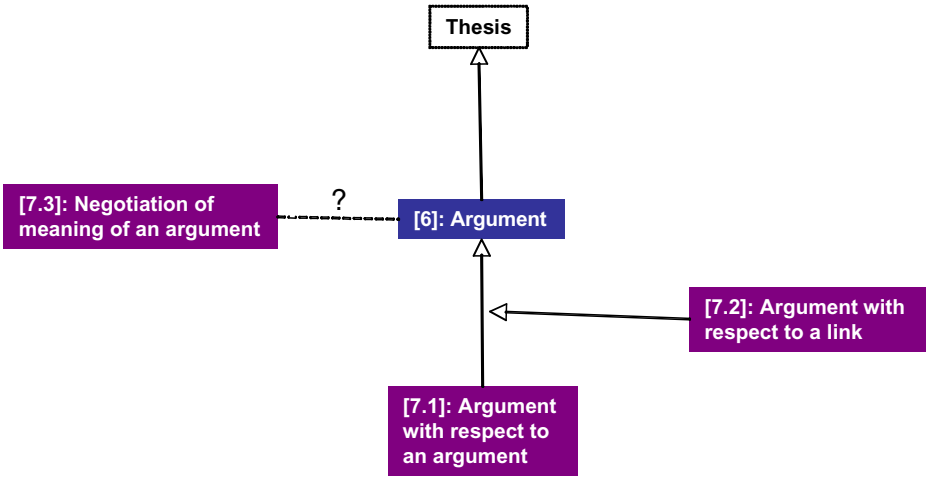

Fig. 3 Operational definition of "broaden and deepen" (Rainbow category 7)

From these two figures, it can be seen that there are three principal ways of broadening and deepening a debate:

7.1 By producing an argument, or a counter-argument, with respect to an argument (one's own or of another participant). This is 'going deeper' in the argument tree. Most probably, this will involve *counter-argumentation*.
7.2 By discussing an argumentative link, such as questioning or supporting that link. In terms of a Toulminian model, this could correspond to backing or warrants of the transition from data to conclusions.
7.3 By discussing the meaning of an argument, or rather, of a key notion that it is built on, or more generally, discursive operations such as reformulation, conceptual

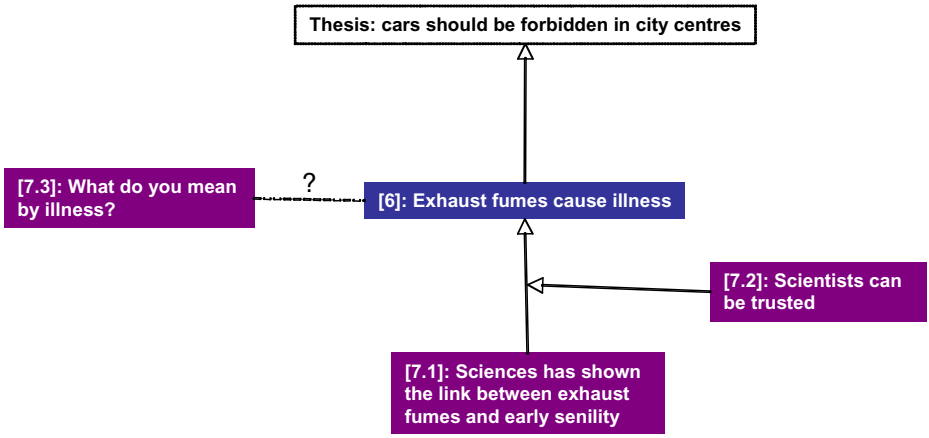

Fig. 4 Instantiation of the "broaden and deepen" category (invented example)

dissociation and association, elaboration of a given argument (Baker 1999), including giving examples.

If we now look back to Extract 4 above, and its graphical argumentation analysis in Fig. 2, it can be seen that Anne's arguments expressed in lines 28 and 30, once analysed as arguments on arguments, would then be re-categorised as "broaden and deepen," subcategory 7.1.

Let us now look at some examples of broadening and deepening in real students' debates.

In extract 5 (Table 6), Aurore introduces a new argument in line 49, of the "slippery slope" type: if we begin with plants we'll do "it" with humans. In lines 50 and 51, the question and its response expand on, or clarify this initial argument. This is "broaden and deepen" of type 7.3, as described above. Incidentally, from a scientific point of view, Aurore's argument is somewhat besides the point, since the biogenetic procedures involved in cloning are nothing to do with those involved in GMOs (as before, our aim is rather descriptive than evaluative). Her argument works on a linguistic and notional level: GMOs are a type of modification of living beings → humans are living beings → cloning is a case of modification of human beings.

In extract 6 (Table 7), Caroline first of all introduces what can be seen as an argument against the negative general thesis, i.e., against *forbidding* production of GMOs: what's the point of forbidding, they will be accepted and authorised in the end?

Aurore's reply, in line 95 can be seen as broadening and deepening this first argument in at least two ways, in fact simultaneously. Firstly, this is an argument against an argument (type 7.1); and secondly, her counter-argument is based on making an argument by dissociation, between what might be argued with respect to "nature" and the "human organism" in particular, and what could be true about (mere) "fashion." Since this is working on the conceptual background of the debate, it is broadening and deepening of type 7.3.

It is significant to note that although the students' discussion here might appear superficial, or even besides the point of the school-based task (they are discussing piercing, makeup and so on), in fact, underlying this discussion is the fundamental notion that needs to be clarified in this debate: "Nature."

Table 6 Extract 5

N	Hh:mm:ss	Loc	CHAT	Rainbow
46	09:44:03	Caroline	but tell me I think that you are against so explain why to me?	5. Opinions
47	09:44:26	Aurore	because it's bad for the human organism	6. Argumentation
48	09:44:55	Caroline	reply to me	3. Interaction management
49	09:45:11	Aurore	and then if we begin with plans in 10 years or less it will be humans' turn	6. Argumentation
50	09:45:38	Caroline	to be modified?	7. Broaden & deepen
51	09:46:02	Aurore	well yeah perhaps we'll even be cloned	7. Broaden & deepen
52	09:46:19	Caroline	yes it's true me you know I'm dead against cloning anyone	5. Opinions
53	09:46:33	Aurore	well yeah me too	5. Opinions

Table 7 Extract 6

N	Hh:mm:ss	Loc	CHAT	Rainbow
94	10:08:12	Caroline	look it's like body piercing at first everyone is against and than affter people chang their mindss	6. Argumentation
95	10:09:16	Aurore	yes but that's a sort of fashion it's not the same in this case nature is at stake and the human organism	7. Broaden & deepen
96	10:09:48	Caroline	i'm 300% in favour in the unique case where it won't lead to any problem at all but we gotta be 600% sure	6. Argumentation
97	10:10:21	Aurore	no I'm 1000 against	5. Opinions
98	10:10:32	Aurore	%	3. Interaction management
99	10:10:51	Caroline	you use makeup all the same but that's not nature it's + or − the same	7. Broaden & deepen
100	10:10:56	Aurore	i'm for it	5. Opinions
101	10:11:11	Aurore	but no it doesn't go inter the organism*	7. Broaden & deepen
102	10:11:34	Caroline	we gotta stopp	4. Task management

In conclusion to this discussion of "broadening and deepening" the space of debate, we remark that what will remain for the purely argumentative category are those arguments that relate directly, on the 'first level' to the main thesis being discussed, and that are not developed further. This has empirical support to the extent that we have observed across a wider set of corpora that students can tend to simply list different types of arguments, across different topics, without necessarily taking them further. A constructive debate is one in which more extended and related chains of arguments occur, in which more precise mutual understandings of the key notions are negotiated.

Interaction analysis with Rainbow: Theoretical–methodological considerations

In the previous section, we presented the Rainbow analysis categories, together with specific aspects of dialogue theory upon which they are based. But the actual carrying out of analyses within this framework raises several fundamental theoretical and methodological issues, of which the analytical point of view, the unit of analysis, analytical decision-making and validating such decisions.

The analytical point of view

The Rainbow analysis categories are clearly *researchers' categories*: they come from problem-solving, dialogue and argumentation theory. However, this does not necessarily mean that these categories are to be applied to single utterances of individual speakers, considered in isolation from the interactive context (*pace* Suthers et al. 2007, who state, p. 1, that "Most studies of online learning assign meaning to contributions in isolation, obscuring the interactionally constructed meaning.").

In applying Rainbow, we do not analyse the beliefs and intentions that are supposedly 'behind' individual speakers' isolated speech acts (*speaker meaning*), but rather the

function of utterances as they emerge from, or are *negotiated* (Roulet 1991) within dialogue itself (*dialogue meaning*). In concrete terms, for the researcher, an utterance counts as, for example, "an argument," for the theoretical reasons mentioned above, but also, and crucially, to the extent that *the interlocutors manifest their shared understanding* of it to be that of an argument. One way of doing this would be to contest its status as an argument, or to provide a counter-argument to it.

In terms of the theory of Clark et al. (e.g., Clark and Schaefer 1989), this is a matter of *grounding*. Conversational participants can manifest their degree of mutual understanding by, for example, relevant continuation; by building on what has already been said one confirms, for example, its status as a proposed solution to a problem. In methodological terms, this means that dialogue meaning must be analysed *retroactively* (at the end of a sequence—see below) and not in a step-by-step fashion, from the beginning of the transcript to the end. The function of a segment depends on where it occurs in the context of the surrounding interaction. "Hi" as the first intervention could have the function "Interaction management: opening, establishing contact"; in the middle of the interaction it might have a social relation function, or indeed anything else. Consider the following example (written in a CHAT, or else uttered with neutral intonation and non-verbal communication), inspired by the work of Edmondson (1981):

[1] A : "It's cold in here."

What is the pragmatic function of [1]? In a sense the question is meaningless, outside a specific interactive context. or rather one that cannot be answered by analysing interaction corpora. Suppose now the following interaction:

[1] A : "It's cold in here."
[2] B : "Oh I'm sorry, I'll put the heating on"
[3] A : "No, no, I like it like that, usually these buildings are overheated"
[4] B : "Ok, fine."

Taking the sequence [1] to [4] as a whole meaningful unit of analysis, the function of [1] is negotiated to be something like "expression of pleasure," not, for example, "indirect request for heat." The point is that it is necessary to interpret [1] in the light of [2]–[4]: "expression of pleasure" is the participants' negotiated meaning of [1], and this is taken into account by the analyst.

In summary, we analyse joint meanings that have emerged from dialogue, on the basis of knowledge of the whole interaction, once it has taken place. Our categories are thus researchers' interpretations of participants' jointly grounded meanings, and not attempts to determine individuals' intentions. This requires looking back and forward in the corpus.

The unit of analysis (segmentation)

Our analysis approach presupposes segmentation of the interaction into meaningful units, to which the categories apply. So far, for the purposes of simplification, we have taken the "CHAT message" as the unit of analysis. This could be defended on the grounds that it corresponds to the participants' own segmentation.

However, for practical reasons (such as the quantity of data to be analysed) and theoretical reasons (the specific research question that the analysis is supposed to help to answer), it may be useful to adopt either a more fine-grained unit of analysis, or else a more macroscopic one. In simple terms, CHAT messages can be segmented so as to

Table 8 Re-segmentation and analysis of extract 4 (in Table 5)

N	Hh:mm:ss	Loc	CHAT	Rainbow	Commentary
24	09:50:03	Anne	Let's talk about GMOs	4. Task management	Introduces topic "GMOs"
25	09:51:06	Anne	and you,	3. Interaction management	Coordination: asks Béatrice to take initiative
			do you think there are any risks?	4. Task management	Introduces subtopic "risks"
26	09:52:24	Béatrice	there's not only foods that will be affected,	6. Argumentation	
			anmals won't be (whether in taste or quality) what they used to be before	6. Argumentation	
26	09:52:24	Béatrice	animals	3. Interaction management	Own communication management (self correction "anmals" =>"animals"
27	09:53:44	Béatrice	of course there are risks even in the domain of health, with the appearance of new viruses, for exmple	6. Argumentation	
28	09:55:52	Anne	yes but there are also lots of medicines that are going to be produced thanks to GMOs and that won't help anything.	6. Argumentation	
			Don't you think so?	5. Opinions	
29	09:57:55	Béatrice	yes itss true	5. Opinions	
			but even in the domain of research things move forward; they discover new vaccinations and others become inefficient	6. Argumentation	
30	09:58:03	Anne	I think that new bacteria will appear because of GMOs and that antibiotics won't be able to destroy them any more	6. Argumentation	
31	09:58:22	Anne	I think that new bacteria will appear because of GMOs and that antibiotics won't be able to destroy them any more	3. Interaction management	Communication management: exact repetition of previous argument either interface 'slip' or else checking contact
32	10:00:08	Béatrice	if I understand you rightly	3. Interaction management	Communication management: checking mutual understanding
			you're against;	5. Opinions	
			but what do you think about	3. Interaction management	Coordination management: asks Anne to take initiative
			ethical problems raised by GMOs	4. Task management	Introduces topic shift "ethical problems"
33	10:02:04	Anne	I think that if we keep going against the laws of nature it will turn back against human beings	6. Argumentation	
34	10:02:35	Anne	Arre you for or against?	5. Opinions	
35	10:03:50	Béatrice	Didn't you understand tht	3. Interaction management	communication management : mutual understanding
			I'm for	5. Opinions	
36	10:04:03	Anne	no against sorry	3. Interaction management	Confirming mutual (mis) understanding, communication management
37	10:04:37	Anne	right, now we'd better sum up	4. Task management	Debate management: move to summing up
			so what do you propose	3. Interaction management	Coordination : asks Béatrice to take initiative

identify separable communicative functions (speech acts), and/or they can be grouped together into meaningful sequences, based on topical and goal-based criteria (Grosz and Sidner 1986).

Such multilevel segmentation and analysis can be based on the "hierarchical–functional" model developed by the "Geneva school" of linguistics (Moeschler 1985; Roulet 1991; Roulet et al. 1991). This model extends the work of Sinclair and Coulthard (1975), and proposes five types of hierarchical units: the speech act, the move, the exchange, the sequence, and the interaction. Conversation is analysed using a semantic grammar that applies to these elements. Segmentation relies on linguistic features (e.g., words like "Ok," "No," "therefore," ..."?" indicating syntax, ...), thematic/topical shifts, the tasks that are being achieved ... but there is no known algorithm or effective procedure that enables such segmentation. For example, a good indicator of the opening of a new exchange is an initiative move such as a question that opens a new exchange. A good indicator of the closing of an exchange is "double accord," or two successive reactive moves, such as "Ok,," "Right." Good indicators for sequences are changes of topic, or opening of new argumentation sequences (the verbal conflict is displaced elsewhere).

Table 8 shows a more fine-grained segmentation of extract 4 (see above) at the speech act level.

It would be possible to make the analysis even more fine-grained. For example, line 28 can be segmented into two different arguments.

Alternatively, a macro analysis, as shown in Table 9, could be carried out, based on identifying argumentation sequences in terms of the global topics addressed.

In Table 9, thick dotted lines indicate boundaries between segments, defined as either argumentation sequences on specific topics, sequences that are concerned with clarifying opinions, or else task management. Note that, for example, the brief autocorrection of line 26 is simply ignored in this case. This is a possible approach, which would probably be complemented by an estimation of the length of argumentation sequences.

Segmentation is a crucial issue when qualitative analytical data is to be transformed into *quantitative* data, to be correlated with learning outcomes. For example, the granularity of segmentation could crucially affect the answer to the question "to what extent was the interaction argumentative?". We may want not only to count occurrences of categories, but also to weight them in terms of the *time* taken up by an activity, possibly in relation to the *number of words* expressed. For example, the analysis could be biased by the fact that an argument expressed quickly in five words counts as "one unit," just as much as does a more extended argument.

Segmentation should supposedly be carried out in a way that is independent from the subsequent analysis. But in practice, given that linguistic clues are not always a sure guide, a message is usually segmented to the extent that the analyst perceives that several analytical categories could apply to parts of it.

Segmentation is crucial for any interaction analysis. Here we have only raised a number of important issues, without claiming to have provided definitive solutions.

Multifunctionality

Depending on their context in the interaction, utterances, or segments of them, can have *multiple communicative functions, simultaneously* (Bunt 1989). Suppose, that a student states the following, in the middle of an interaction:

let me explain to you how allowing modifying nature leads to cloning.

Table 9 Macro analysis of extract 4 (in Table 5)

N	Hh:mm:ss	Loc	CHAT	Rainbow
24	09:50:03	Anne	Let's talk about GMOs	4. Task management
25	09:51:06	Anne	and you, do you think there are any risks?	6. Argumentation: *health risks*
26	09:52:24	Béatrice	there's not only foods that will be affected, anmals won't be (whether in taste or quality) what they used to be before	
26	09:52:24	Béatrice	animals	
27	09:53:44	Béatrice	of course there are risks even in the domain of health, with the appearance of new viruses, for exmple	
28	09:55:52	Anne	yes but there are also lots of medicines that are going to be produced thanks to GMOs and that won't help anything. Don't you think so?	
29	09:57:55	Béatrice	yes itss true but even in the domain of research things move forward; they discover new vaccinations and others become inefficient	
30	09:58:03	Anne	I think that new bacteria will appear because of GMOs and that antibiotics won't be able to destroy them any more	
31	09:58:22	Anne	I think that new bacteria will appear because of GMOs and that antibiotics won't be able to destroy them any more	
32	10:00:08	Béatrice	if I understand you rightly you're against; but what do you think about ethical problems raised by GMOs	6. Argumentation: *ethical issues*
33	10:02:04	Anne	I think that if we keep going against the laws of nature it will turn back against human beings	
34	10:02:35	Anne	Arre you for or against?	5. Opinions
35	10:03:50	Béatrice	Didn't you understand tht I'm for	
36	10:04:03	Anne	no against sorry	
37	10:04:37	Anne	right, now we'd better sum up so what do you propose	4. Task management

This utterance can have several functions, including interaction management (requesting right to speak, proposing a shift of topic) and argumentative functions (a criticism/attack/counter-argument with respect to allowing GMOs).

Moving on to a real corpus example, what is the function of the utterance in line 33 of extract 7 (Table 10)?

Table 10 Extract 7

N	Hh:mm:ss	Loc	CHAT	Rainbow
29	09:44:27	Susan	I've got nothing left to say	
30	09:44:34	Alma	yeah 1 hours feels a long time	
31	09:44:59	Alma	Well then ask mye a question	
32	09:46:56	Susan	I feel empty. Haven't you got a question ?	
33	09:47:19	Alma	right, don't you think that gmos will destroy nature ?	**??**
34	09:48:43	Susan	yes, with chemicl products that pollute soil and water	
35	09:49:53	Alma	yes	

In this interactive context, the utterance "right, don't you think that gmos will destroy nature?" could have the following communicative functions:

> an argumentative function: asking this question in a negative form ("don't you") carries the presupposition that the speaker believes that gmos might destroy nature. She may also be asking her partner for an opinion.
> a task management function: Alma has introduced a new topic for debate;
> in some sense, it has a socio-relational function: it is clear that Susan is tired, bored, demotivated; complying with her request cements their cooperative bond.

How are analytical choices to be made? The first response would be to avoid such a choice, to add separate columns of categories for cognitive, social and management functions, with categories in each. But if, for some reason (such as desire to simplify analysis for quantitative measures) it were decided to make a unique choice amongst functions, then criteria of explicitness and contextuality would apply. In this case, utterance 33 follows a sequence of interaction management, and introduces explicitly a new topic in the GMO debate (destruction of nature), in response to an explicit request ("haven't you got a question?). Its argumentative function is not explicit; it depends on a presupposition (Alma did not in fact say "I think that GMOs will destroy nature"). In addition, it is followed by a specific argument against GMOs relating to this same topic. If 33 is task management, then it would be coherent to consider what precedes it (a request for a question to be debated) as belonging to the same category. Our analysis would thus as shown in Table 11.

Validation of the Rainbow framework

Rainbow has been validated across a variety of collaborative learning situations within the SCALE project (see footnote 1), in terms of intersubjective agreement between analysts and the ability of the framework to identify categories of interaction that relate to learning outcomes. A selection of this research is described below.

Baker et al. (2003) used the Rainbow framework to analyse two types of pedagogical debates between high school students (16–17 years old), on the question of the authorisation of the production of GMOs (Genetically Modified Organisms): (1) CHAT debates, and (2) debates that took place via the DREW interactive argument diagram tool (see Fig. 5 below) on shared a web space, together with concurrent use of a CHAT (mostly for interaction management). Three researchers analysed the interactions with the rainbow framework; inter-coder reliability was excellent ("CHAT only" experimental condition: Kappa=0.91, SE=0.01, T=45.29, p<0.01; "Chat-argument-diagram" experimental condi-

Table 11 Extract 7 (revisited)

N	Hh:mm:ss	Loc	CHAT	Rainbow
29	09:44:27	Susan	I've got nothing left to say	3. Interaction management
30	09:44:34	Alma	yeah 1 hours feels a long time	3. Interaction management
31	09:44:59	Alma	Well then ask mye a question	3. Interaction management
32	09:46:56	Susan	I feel empty. Haven't you got a question ?	4. Task management
33	09:47:19	Alma	right, don't you think that gmos will destroy nature ?	4. Task management
34	09:48:43	Susan	yes, with chemicl products that pollute soil and water	6. Argumentation
35	09:49:53	Alma	yes	5. Opinions

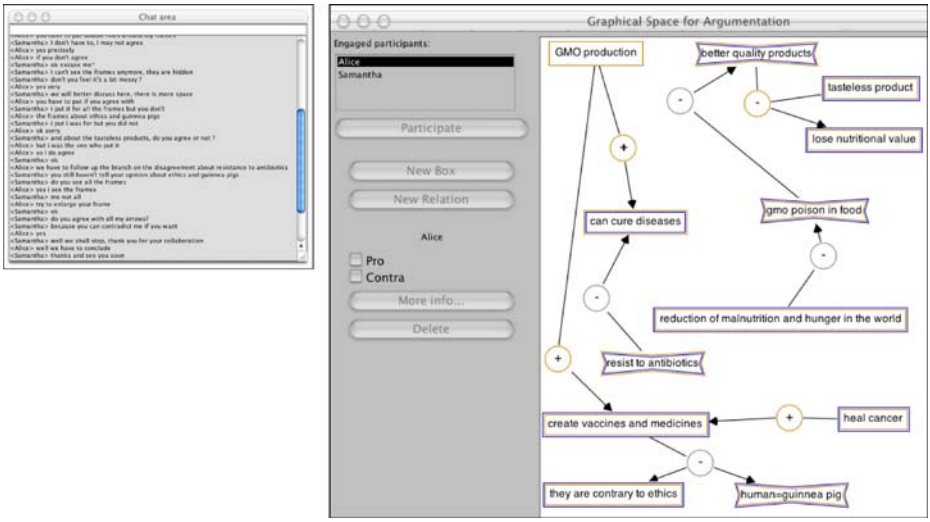

Fig. 5 DREW interfaces (CHAT on left, argument diagram tool on right)

tion: Kappa=0.94, SE=0.006, T=83.38, p<0.01). This showed that the framework could be used for comparative analysis, where there is functional equivalence between communicative acts across the two media. For example, in the CHAT only case, an argument corresponds to part of a typed message, whereas in the diagram, it corresponds to constructing, labelling and linking a box to another. Across conditions, non-argumentative activities (rainbow categories 1 to 4) were shown to take up a much higher percentage (64.42%) of the students' activities than argumentative activities themselves. Supplemental t tests indicated that the relative proportions of argumentative activities (categories 5, 6 and 7) were significantly higher for students assigned to the "CHAT only" condition (51.79%) than for those assigned to the "CHAT-GRAPH" condition (22.60%) (p<0.01). This research produced a surprising result: the only interaction category, as defined by Rainbow, that was significantly correlated with significant pre-post test gains was category 4 (task management): the more the students re-organised their diagrams on the screen, the more they remembered new arguments at the end of the session.

Van Amelsvoort et al. (2007) investigated the conditions under which diagrammatic representations support collaborative argumentation-based learning in a computer-environment. Thirty pairs of secondary school students (15–18 years old) discussed and wrote about Genetically Modified Organisms. Students prepared by constructing a representation (text or diagram) individually. Then they discussed the topic and wrote a text in dyads. They consolidated their knowledge by revising their individual representation. There were three conditions: pairs of students could inspect either (1) the individual texts they wrote, (2) the individual diagrams they constructed, or (3) a diagram that was constructed for them based on the text they wrote. The Rainbow framework was used to analyse students' activities in chat and writing. Inter-rater reliability on ten protocols was 0.82 (Cohen's Kappa). This study shows that the Rainbow framework can be applied to all activities students carry out in the collaborative environment, revealing the mix of activities in CHAT and writing. Most striking in the results was the fact that students investigated a large amount of their activities (66%) in managing the task, specifically the writing task. For example, the students discussed who was to write, counted the words of their text,

looked at their individual texts or diagrams, or worked on structure or spelling of the text. About 16% of all activity was spent on content interaction (Categories 5, 6, and 7), chatting and writing about GMOs.

Litosseliti et al. (2005) compared argumentative debates in oral and written (electronic chat) modes, and between two cultures of education: British and Finnish secondary schools (15–19 years old students). The authors report inter-rater reliability figures of using Rainbow 0.91 and 0.72. In both cultures, high percentages of opinions, argumentation, and broaden and deepen were reported. The differences between Rainbow categories for electronic and face-to-face modes were not substantial, albeit somewhat more in favour of the face-to-face communication mode for argumentative categories. The authors conclude that Rainbow was useful as a descriptive tool for analysing interaction during collaborative problem solving.

The research cited above shows that Rainbow can be systematically and validly applied, in ways that are relevant to explaining learning outcomes, across a variety of argumentation-based CSCL situations, involving use of CHAT, interactive argument graphs, collaborative writing and face-to-face interactions.

Extensions to the Rainbow framework

Rainbow has been described here with respect to pedagogical debates carried out with a CHAT system. As we described above, it has been consistently applied to other types of (non-)mediated interactions. Below, we discuss possible extensions to the framework (some of which have been put into effect), to cover more complex CSCL situations, and other types of collaborative problem-solving tasks.

Topical analysis

Understanding the extent to which students have knowledge of a space of debate also relates to the range of different topics or viewpoints that they discuss. More specifically, topical categories can be crossed with Rainbow functional categories to determine, for example what are the topics most and least discussed, by which students, are they associated more with pro or contra argumentation, what are the topics that are deepened, and so on. Such a list of topical categories often needs to be developed ‘by hand’ (but lexical analysers could also be useful), on the basis of topics dealt with in teaching materials, but also new ones that students themselves introduce in interactions.

Table 12 Themes and social actors for the GMOs debate

Topic	Opinion	Limagrain	Greenpeace	Ministry	The Press
Health	For				
	Against				
Environment	For				
	Against				
Affluence/welfare	For				
	Against				
World view	For				
	Against				
Other					

For example, in the SCALE project, we based topical analysis on general themes, together with the social actors (e.g., Greenpeace, grain producers, ministry of science, etc.), as shown in Table 12 below. This distinction is important since "the facts"—even supposedly scientific ones, concerning health and agriculture—can be represented from different points of view.

A more detailed topical analysis for the GMO debate can be found in Table 15 of Appendix A. Such a topical analysis of extract 6 (see above) is shown in Table 13 (clearly, interaction management rarely has a topic).

Topical analysis presents specific problems with respect to choice of the unit of analysis. The unit of analysis of domain content analysis is the simple proposition or the complex conditional proposition. An example of a simple proposition is "People will have more food." An example of a complex conditional (IF X-THEN Y, or Y since X, or Y because X, etc.) is "[People will have more food] so [economic inequality decreases]." This proposition is complex since it regroups two separable propositions; it is conditional since it expresses a causal or temporal relation between them. Conditional propositions represent students' reasoning.

In complex conditional propositions, we need to decide which is the main topic to be analysed. We choose it to be the topic of the conclusion of the conditional proposition, since this is what is being focused on, or reasoned for. For example, in "[People will have more food] so [economic inequality decreases]," or "[Economic inequality decreases] since [people will have more food]," the dominant proposition, whose topic is chosen for the whole proposition, is that of "[economic inequality decreases]," i.e., "affluence."

Table 13 Extract 6 (revisited)

N	Hh:mm:ss	Loc	CHAT	Rainbow	Topics
94	10:08:12	Caroline	look it's like body piercing at first everyone is against and than affter people chang their mindss	6. Argumentation	World view//Human —Nature
95	10:09:16	Aurore	yes but that's a sort of fashion it's not the same in this case nature is at stake and the human organism	7. Broaden & deepen	World view//Human —Nature
96	10:09:48	Caroline	i'm 300% in favour in the unique case where it won't lead to any problem at all but we gotta be 600% sure	6. Argumentation	Other//safety
97	10:10:21	Aurore	no I'm 1000 against	5. Opinions	GMOs
98	10:10:32	Aurore	%	3. Interaction management	
99	10:10:51	Caroline	you use makeup all the same but that's not nature it's + or − the same	7. Broaden & deepen	World view//Human —Nature
100	10:10:56	Aurore	i'm for it	5. Opinions	World view//Human —Nature .e. for wearing makeup
101	10:11:11	Aurore	but no it doesn't go inter the organism*	7. Broaden & deepen	World view//Human —Nature
102	10:11:34	Caroline	we gotta stopp	4. Task management	

With other complex propositions, such as those where two propositions are conjoined, or where there is simply a list of propositions, each proposition has a separate topic analysis, since the propositions most probably correspond to different arguments.

Graphically-mediated debates

Since the work of Suthers et al. (e.g., Suthers et al. 1997), and the Belvedere system, a significant amount of work in CSCL has been concerned with the use of shared diagram-based interfaces, for what Suthers terms "evidential reasoning," or in our case "argumentation" (see Andriessen et al. 2003a, for a synthesis). Within the SCALE project, the Rainbow framework has in fact been developed in order to analyse both CHAT interactions, as presented above, and diagram-based argumentative interactions. Clearly, we wanted a method that enabled experimental comparison between the two types of interactions.

The principal graphical interface of DREW (Dialogical Reasoning Educational Webtool: Corbel et al. 2002; Quignard 2000), developed within SCALE is shown in Fig. 5.

The DREW argument-diagram tool consists of three basic elements. Firstly, boxes represent statements, such as "heal cancer," or "they are contrary to ethics." The content of these boxes can be elaborated on by double-clicking on them; this content is made commonly visible on the shared screen when the mouse is moved over the boxes. Secondly, boxes can be linked together with arrows, labelled "+" (for positive argument," "–" (for a counter-argument), or else "undefined." Once statement boxes become linked together in this way, they take on the value of arguments, counter-arguments or theses (a thesis is a box that has at least one argument and one counter argument, and/or different opinions expressed with respect to it—see below). Thirdly, the interface reifies the distinction between argument and opinion: for every element of the diagram (box or arrow), student–participants, defined by their distinctive colours, can select them and express either a "pro" or a "contra" opinion with respect to them (using the checkboxes to the left of the interface). When different opinions from different participants are expressed with respect to a given item, it changes its shape to be "scrunched" (see, for example, the box marked "human=guinea pig" above), in order to focus the debate on this item. Such opinions (expressed on nodes) are distinct from (counter-)arguments, that are expressed using links, as described above.

Rainbow is adapted to analysing interactions with DREW as follows (Table 14).

Note that in the above example, the students can also use a CHAT interface, for interaction management, discussing the meaning of arguments, and so on. In addition to noting Rainbow categories, an important research question is that of the sharing out of activity across the two different communication interfaces.

Other types of problem-solving interactions

As we discussed above, debates are specific forms of problem-solving interactions, that do not involve direct intervention in the cognitive problem itself. The actual "problem-solving" categories in this case are 4, 5, 6 and 7. They can thus be readily adapted for analysing other types of problem-solving interactions.

For example, suppose that students are trying to solve a mathematics problem together, with pencil and paper. In this case, the first three categories (1. Outside activity, 2. Social relation, 3. Interaction management) remain the same as defined previously. Task management (4), in the present case, is generalised to any form of *regulation* of problem-

Table 14 Rainbow categories adapted for analysing graphically-mediated debates

Rainbow category	Instantiation with graphical interface
1. Outside activity	Defined as in Table 1. This could include, for example, using a statement box to make a remark such as "What do you think of Madonna's new album?".
2. Social relation	As with category 1: using a box to express, for example, fun remarks, frustration, rather than an argument.
3. Interaction management	Usually this will be expressed using the CHAT interface, for example to agree or disagree on who will draw what on the argument diagram tool. However, work on the level of interaction management can be observed from transcripts by observing, for example, repeated sequences of contradictory actions, such as one student creating an arrow, the other deleting it, then the first creating it again, and so on.
4. Task management	In this case, task management can include creating a box representing a new thesis, on a new topic, to be argued, but also, rearranging the diagram, for example to group arguments on the same topic together, or to group arguments on one side and counter arguments on the other.
5. Opinions	In the argument diagram interface, this is expressed explicitly, with the "pro" and "contra"checkboxes. However, we have observed that students often 'play' with this interface feature, or perhaps hesitate in relation to one argument, with a sequence of, for example, "pro, contra, pro, contra, pro" opinions. In this case, it would count as just a single unit of expression of opinions.
6. Argumentation	This could be thought to correspond to the simple creation of a box with a statement in it. However, this does not become argumentation until the box is actually linked, argumentatively, to another. This category also includes retraction of arguments (it must be checked contextually that this is not just an interface slip).
7. Broaden and deepen	This category includes adding elaborations, examples and so on inside the argumentation boxes, elaborating on their names themselves and—this is easily observable in this case—making arguments on arguments (going down in the argument tree).

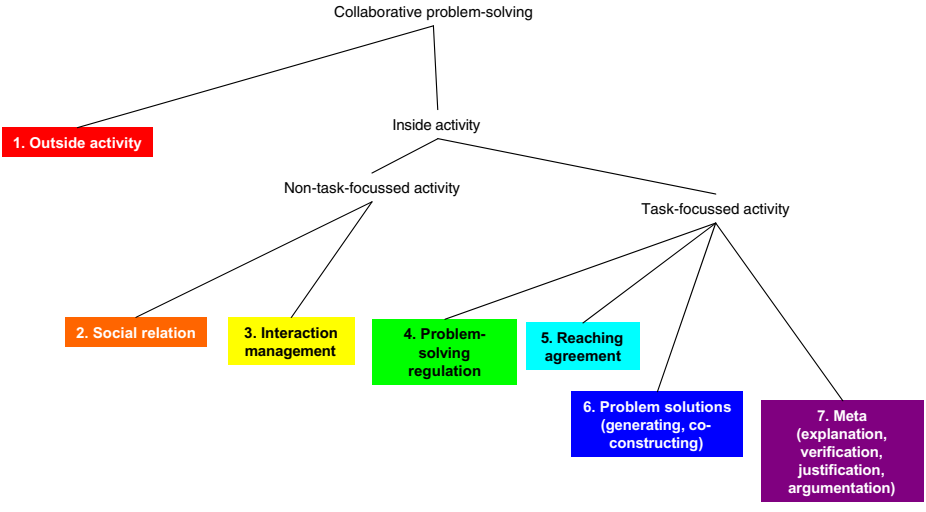

Fig. 6 Generalisation of Rainbow to other types of problem-solving interactions

solving (discussing strategies). The Opinions category (5) will concern all explicit interaction concerned with establishing agreement. Since in the debating task, "6. Argumentation" concerns the means of solving this type of problem, in a general problem-solving interaction, this would correspond to expression and co-construction of problem solutions. Finally, the category "7. Broaden and deepen" can be seen here as any interaction concerned with knowledge-centred metacognition: providing explanations, verification, arguments, justifications. Figure 6 shows such a possible generalisation of the Rainbow method. In fact, this corresponds closely to the method described in Baker and Lund (1997) that was devised for analysing computer-mediated interactions where students drew energy chain diagrams together.

Conclusion

The Rainbow framework, described in this paper, was designed for analysis of computer-mediated debates, and the extent to which students are engaged in a specific form of knowledge elaboration: broadening and deepening understanding of a space of debate.

As mentioned in the literature review above, most of Rainbow's analysis categories have been already described in existing research, with the exception of the most important one: "Broaden and deepen." More generally, the strength of the Rainbow framework resides in the fact that these categories are synthesised into a coherent whole, on the basis of broad and explicit theoretical foundations, derived from diverse schools of thought on the nature and structure of interaction, conversation, dialogue and argumentation. Rainbow is termed a "framework" rather than a "method" for analysis here, precisely because it is stated at a sufficiently general level so that new subcategories can be added that are specific to the situation being studied. We have described and illustrated the use of Rainbow in sufficient detail so that it could be used and adapted by other researchers.

Several of the analytical distinctions on which Rainbow is based are difficult to make in theory as well as in practice—for example, between inside and outside the activity, between social-relation oriented interaction and interaction management. We would argue, nevertheless, that these are the main distinctions that need to be made in the analysis of collaborative argumentation-based learning. We described above that above and beyond these difficulties, analysts have been able to attain a significantly high degree of intersubjective agreement, across a variety of collaborative learning tasks and tools (CHAT, spoken interactions, graphically-mediated interactions, computer-supported collaborative writing).

Whilst Rainbow was initially designed as a "code and count" method, to be used in statistical comparisons, the major functional units that it identifies are not incompatible with detailed process-analysis approaches. Once functional units such as argumentation and broaden/deepen have been identified, the analyst can zoom into certain key sequences in more detail. In fact, identification of argumentation itself often requires some degree of process-analysis to be carried out (e.g., identifying to which previous claim a statement relates in order to categorise it as a counter-argument), at least implicitly.

In terms of CSCL re-design (e.g., the DREW interface, shown in Fig. 5), Rainbow has not only been useful in determining the extent to which the software, once embedded in a pedagogical task sequence, enables pedagogical objectives to be achieved. It also has been used to focus analysis on potential coordination problems that the collaborating students might have, as represented by the "interaction management" category. Clearly, that interaction management takes place, for example in the form of coordinating who will perform what interface action, is not necessarily a negative thing: the category needs to be

subjected to a deeper analysis. It is only when this is detrimental to achieving the learning goals, that interaction management can be seen in a negative light (e.g., when nearly all the interaction is coloured yellow, for interaction management, rather than violet for knowledge elaboration, it can be hypothesised that the first is carried out at the expense of the second).

The authors of this paper have found Rainbow to be a useful "boundary object" (Star 1989) in research and university-level teaching on the theme of interaction analysis in education. The fact that Rainbow contains a small and determinate number of categories (however easy or difficult they may be to apply), and requires the making of determinate and unique analytical choices (notwithstanding a certain degree of theoretical simplification), has stimulated productive discussions about what is really meant by, for example, "interaction management," "argumentation" and "knowledge elaboration" (especially during Interaction Analysis masters courses given by the authors of this paper, for example at the universities of Lyon, Paris, Utrecht and Stockholm). To that extent, we expect Rainbow to also stimulate the creation of its own 'clone' analysis methods.

Finally, we mentioned earlier that the colour coding of Rainbow could allow interaction data visualisation. At the present stage of our research, this is merely an informal aid for the analyst. In future research, we intend to explore the possibility of data visualisation using semi-automatic pattern matching techniques, with the aim of identifying the types of interactive sequences in which knowledge elaboration most frequently occurs.

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Appendix A

Table 15 More complex analysis of topics for the GMOs debate

Topic	Subtopic	Explanation	Examples arguments pro	Examples arguments contra
Health	Nutrients	Arguments about the effect GM can have on people's health by adjusting, adding and removing certain nutrients.	With GM you could add vitamins, so food gets healthier. With GM you could get rid of nutrients that increase the cholesterol level.	By adding new proteins, people can get allergic to many kinds of food. It is not necessary to create healthier food, people just need to eat a bigger variety of food.
	Diseases	Arguments about the effect GM can have on people's health by means of controlling diseases and illnesses, and the use of antibiotics in	Human diseases like diabetes can be cured by means of producing insulin with GM. Genetically modifying genes can prevent the occurrence of genetic	Bacteria will get resistant to antibiotics because antibiotics are used in producing GM-things. New diseases emerge

Table 15 (continued)

Topic	Subtopic	Explanation	Examples arguments pro	Examples arguments contra
		developing GM products.	disorders like Down's syndrome. Hereditary diseases can be investigated	
Affluence/ Welfare	Hunger and food	Arguments about the effect GM can have on people's affluence/ welfare, in particular world hunger.	More food production with GM diminishes hunger in the Third World.	World hunger is not due to a lack of food, but a lack of equal division of food. GM will thus not solve the food problem.
	Division of affluence	Arguments about the effect GM can have on people's welfare, in particular the unequal division of resources in the West and the Third World.	Farmers in the Third World could produce more food with GM products, and thus make more money. More food production in the Third World creates more work	Farmers will become dependent on multinationals who have the patent right for GM-seed. Farmers in warm countries will lose market when products can be produced everywhere. The developing countries become more dependent on the western countries. Only the western countries benefit from GMO because of the high price, inequality increases
	Costs and benefits	Arguments about the effect GM can have on people's welfare regarding costs and benefits of the technique.	GM is an important source of money in a country. If trees grow faster we will make more profit	GM is too expensive
	Consumer	Arguments about the consequences of GM for the consumers.	Rules will ensure that consumers still know exactly what they are eating.	Consumers will not know whether they eat GM food or natural food. GM food is not cheaper for the consumers/is expensive. People will become dependent on GMO-food
Environment	Diseases and weeds	Arguments about the effect GM can have on the environment when talking about control	With GM you could protect crop from diseases and insects, so you won't need any	It will be so easy to use pesticides that farmers will use them much more.

Table 15 (continued)

Topic	Subtopic	Explanation	Examples arguments pro	Examples arguments contra
		of plant and animal diseases, and weeds.	pesticides anymore. The development of pesticides. With GM you can prevent cows from getting BSE.	
	Agriculture	Arguments about the effect GM can have on the environment when talking about producing agricultural crops	By means of GM we will get stronger plants, bigger harvests, so we won't need that many acres for agriculture. By means of GM we will get stronger plants that grow more easily, so we won't need that much energy, water, fuel and fertilizer. With GM you could adjust plants in such a way that greenhouses are not necessary, so you need less energy for growing vegetables and fruits.	People won't use less acres. They want to produce more food, so will use all available acres. Biological agriculture is threatened by GM. Because the pollen of GM plants can mix with the plants of biological agriculture.
	Nature	Arguments about the effect GM can have on the environment, in particular the quality of natural surroundings.	GM organisms can clean polluted soil. With GM we don't need that many acres to grow food on anymore, so less tropical forest will disappear.	GM threatens the diversity and variety of species (biodiversity). The ecosystem will become confused, the balance of nature will be disturbed
World view	Progress/ development	Arguments about the place of GM in scientific and technological developments.	We have always had crosspollination of plants. GM is more effective than traditional crossing. You cannot stop technological developments like GM. GM stimulates scientific progress and possibilities for mankind. Clarifying what kind of effects genes have. Developing the human genotype to be more adaptable. Gene transfer technique is an excellent tool to do researchBy research it is posssible to foresee the futureChildlessness can be treated by GMO	There are boundaries in human progress. Humans must not want everything. GM is not necessary. W e can also use the traditional crossing. GM is not necessary. There are enough healthy products. Only those who do scientific work benefit from GMO. The development of viruses by GMO "Cloning Hitler"

Table 15 (continued)

Topic	Subtopic	Explanation	Examples arguments pro	Examples arguments contra
	Human—Nature	Arguments about the place of GM in the discussion about the relation between mankind and nature/God.	People are always messing with nature, for example crossing plants GM should be possible too.	GM goes through the barriers of species and that is just a step too much in mixing up nature. Humans are not allowed to change nature. We are not allowed to play God. More testing on animals is needed People should not experiment on animals or humans
Other	Safety (vague)	Arguments about the consequences of GM for the safety of people in general.	Normally people don't worry about the safety of all kinds of techniques, so why would they worry now?	GM is not yet proved to be safe. Gene manipulated species may behave in an unpredictable way
	Conditionals	Arguments that could be seen as conditional upon opinions, arguments that restrict the opinion	If by means of GMO things can be done that cannot be done without GM, it should be allowedIf the pro's outweigh the con's, it should be allowed	There need to be more research before it can be allowed
	Rest	Arguments that do not fall into any of the other categories		▪When it is possible to read our genes as bar codes we won't have privacy anymore

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