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How do argumentation diagrams compare when student pairs use them as a means for debate or as a tool for representing debate?

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Abstract The objective of the research presented here was to study the influence of two types of instruction for using an argumentation diagram during pedagogical debates over the Internet. In particular, we studied how using an argumentation diagram as a medium of debate compared to using an argumentation diagram as a way of representing a debate. Two groups of students produced an individual argument diagram, then debated in pairs in one of the two conditions, and finally revised their individual diagrams in light of their debate. We developed an original analysis method (ADAM) to evaluate the differences between the argumentation diagrams constructed collaboratively during the interactions that constituted the experimental conditions, as well as those constructed individually before and after debate. The results suggest a complementary relationship between the usage of argumentation diagrams in the framework of conceptual learning. First, students who were instructed to use the argumentation diagram to represent their debate were less inclined to take a position in relation

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to the same graphical element while collaborating. On the other hand, students who were instructed to use the argumentation diagram alongside a chat expressed more personal opinions while collaborating. Second, the instructions given to the participants regarding the use of the argumentation diagram during the collaborative phase (either for debate or for representing a chat debate) have a significant impact on the post-individual graphs. In the individual graphs revised after the collaborative phase, participants who used the graph to represent their debate added more examples, consequences and causes. It follows that a specific usage for an argumentation diagram can be chosen and instructions given based on pedagogical objectives for a given learning situation.

Keywords Argumentation diagram · CSCL · Socio-cognitive conflict · Multiple external representations · Pedagogical debate

Introduction

Research on collaborative argumentation-based learning has recently emerged as a special focus within the domain of Computer Supported Collaborative Learning (CSCL; Andriessen et al. 2003). It is now widely agreed that helping students learn how to argue about knowledge is favorable for learning (Andriessen and Coirier 1999; Baker et al. 2001). First, students who elaborate defenses or attacks of their own or their partner's assertions must examine their own beliefs and understand the beliefs of their partner. Such examination of beliefs, coupled with the elaboration of argumentative discourse, can help students differentiate conceptual notions (Baker 2003), elaborate new knowledge (Baker 1999), develop arguments (Séjourné et al. 2004) or justify their viewpoints (Sandoval et al. 2000). Considering that justifications are special types of explanations, this last point links to the literature on the "self-explanation effect," where subjects that are asked to "self-explain" their solutions show better problem-solving performance (Chi et al. 1989; Chi & VanLehn 1991). Second, as a result of argumentation, students may recognize that their point of disaccord cannot be resolved without obtaining further knowledge, perhaps from their teacher (De Vries et al. 2002).

Research on learning activities in CSCL that are based on argumentation has experimented with many different ways to help students learn how to argue about knowledge. They include writing argumentative text (Coirier and Golder 1993; Veerman et al. 2002), engaging in supported discussion or debate (Stegmann et al. 2004; De Vries et al. 2002) and creating argument diagrams (Baker et al. 2003; Suthers and Hundhausen 2003). Various tasks, tools and learning situations have been elaborated for each of these activities in order to better understand the relationship between them and the elaboration of knowledge through argumentation.

The research reported here was developed within this framework and was carried out by the Lyon team in the context of the European project SCALE,[1] the general goal of which was to present theoretical and pedagogical foundations for the design of situations that favor Collaborative Argumentation-Based Learning (CABLE).

[1] The "SCALE" project (Internet-based intelligent tool to Support Collaborative Argumentation-based LEarning in secondary schools) was financed by the European Union "Information Societies" Technologies (IST) programme (IST-1999-10664) of the 5th framework between 2001 and 2004; http://www.euroscale.net, http://drew.emse.fr.

Our team carried out two major experiments within SCALE, the second of which explored the results of the first and will be presented in detail here. The first experiment illustrated that participating in typewritten "chat" interactions and constructing argument diagrams with an argumentation-graph tool (JigaDREW-designed and developed within the project), were both equally effective in helping students to subsequently produce significantly higher quality argumentative texts.[2] However, in each case (for chat and for argument diagrams), different interactive learning processes were at play. Namely, the chat interactions were significantly more argumentative, and this correlated with the subsequent production of higher quality argumentative texts. In the argument diagram interactions, the arrangement or moving of boxes containing arguments was correlated with the subsequent production of higher quality texts (Baker et al., in preparation). Chat interactions may thus be more effective for elaborating arguments, perhaps due to the "strategic indeterminacy" (Edmondson 1981) of language-based interactions. In other words, greater ambiguity favors more negotiation of meaning. On the other hand, unsurprisingly, argument diagram interactions seem more effective for displaying argumentation structure and thus facilitating the incorporation of new arguments into the space of debate.

The experiment carried out in the second year of the SCALE project explored two specific tasks based on the JigaDREW argumentation-graph tool in order to determine precisely how these tasks favor elaboration of argumentative knowledge in collaborative learning situations. Given that higher quality argumentative texts correlated with arranging boxes containing arguments, but that the chat interactions were significantly more argumentative than the graph interactions, it seemed pertinent to look more closely at argumentation-graph usage in order to understand how changing the instructions for using a tool can change outcomes in general and, more specifically, potentially favor more argumentative knowledge construction. Based, in part, on the first year results of SCALE, Munneke et al. (2003) showed that using a diagram during discussion did not lead to more depth in discussion than using one before discussion. Our second year experiment was designed in order to answer the following questions:

– How does changing how students use an argumentation graph during a debate on important societal questions influence their learning about the space of debate? More specifically, what kinds of interactive learning mechanisms are facilitated when students use an argumentation graph (1) as a medium of debate or (2) as a way of representing a chat debate?
– If differences in students' learning about the space of debate can be discerned as a function of argumentation graph usage, how does this influence the design of CSCL systems and the learning situations in which they are embedded?

Research background

The questions we address in this article focus on two main crossroads of research: (1) argumentation, CSCL and learning and (2) multiple external representations and collaborative learning. In the following sections, we will review research results pertinent to studying

[2] Higher quality was evaluated in terms of two measures: (1) QED (Qualité de l'Espace de Débat or Quality of the Space of Debate) and (2) Rainbow (a measure of the types of interactions within a debate).

how differing the instructions for use of an argumentation graph *during* computer-mediated debate changes the manner in which students collaborate and revise individual argument graphs *after* such debate. The manner in which they revise their graphs is considered to be a type of learning, originating in debate. The above-mentioned crossroads of research will be reviewed in relation to the four principal roles of the computer in CSCL environments identified by De Vries et al. 2002): (1) the computer as a collective memory of what has been constructed; (2) the computer as the focusing point of dialogue and action; (3) the computer as a means of representing elements in a discussion and (4) the computer as a medium for communication. Each of these roles, depending on where they occur in a given pedagogical sequence and depending on what type of external representation is used to carry them out, may have different effects on learning goals. In addition, they often exist concurrently.

Argumentation, CSCL and learning

Theoretical notion

The socio-cognitive conflict paradigm (Doise and Mugny 1981) supports the notion that argumentation is considered to be beneficial for collaborative learning. This paradigm is based on the original concept of conflict from Piaget between a student's cognitive structure and the structures he or she encounters in the inanimate environment. This conflict is seen as a motor for change in that the two conflicting structures are integrated by the student into a unified *re*-structured whole. The transposition of the conflict to the social plane (between people) makes it *socio*-cognitive and its cooperative resolution can also lead to conceptual change (Chi et al. 1994; diSessa 1993; Vosniadou 1994).

CSCL interfaces for argumentation

CSCL environments have thus been built and pedagogical sequences have been organized in order to provoke socio-cognitive conflicts between collaborative problem-solvers and to subsequently help them resolve these conflicts and restructure their knowledge. The CSCL environments pertinent for our research are those built around the general notion of an argumentation graph or diagram. The Belvedere system (e.g., Suthers et al. 1997) is one of the precursors of such an environment, providing for the construction of diagrams expressing "evidential reasoning." In Belvedere, students construct diagrams that relate different types of evidence to hypotheses, using data to support a hypothesis or show that a theory conflicts with it, for example. Research on the early Belvedere interface showed that students focused excessively on choosing an epistemic category for their contributions. In other words, if the task was to discuss why the dinosaurs became extinct, students spent more time considering what counted as a theory, hypothesis or claim than actually elaborating them. In Suthers' more recent research, the Belvedere interface has thus been simplified, allowing participants to concentrate on content and distinguish between ideas that are empirically backed or merely suggested. In a similar vein, Baker & Lund (1997) showed how structuring a CSCL interface could lead to a more task-focused and reflective interaction, rather than one focused on interaction management. However, whereas in both studies the interface mattered, in the research on Belvedere the interface was simplified to allow for focus on content while in Baker & Lund a structured communication interface provided shortcuts for interaction and task management as well as for coming to agreement.

The goal of a more reflective interaction through focusing dialogue and action was met in both cases, but not by the same specific means. In the first case, elements representing the discussion were simplified and in the second, the communicative interface was structured.

In terms of identifying the mechanisms for knowledge construction in CSCL, Suthers (2005) showed how interaction *through* evidential reasoning allowed for: (1) grounding by participants implicitly taking up a partner's actions in the graph, (2) interactions that respond to and address differences in interpretations and (3) transformations of representations by multiple individuals leading to a joint solution. Our own research on argumentation in CSCL has provided evidence for similar types of cognitive and interactive mechanisms important for learning: co-elaboration of new knowledge driven by a need to resolve socio-cognitive conflicts between students (Baker 1999), differentiation of conceptual notions when students attribute different meanings to the same term (Baker 2003; De Vries et al. 2002), and development of counter-arguments in the context of dialogical exchange (Séjourné et al. 2004; Baker et al. 2003).

Pedagogical sequences

The organization of pedagogical sequences within which CSCL systems are embedded is important for instigating and cooperatively resolving a socio-cognitive conflict and reaching learning goals. This research goes under the heading of "scripting collaboration" (Dillenbourg 2002), building "learning scenarios" (Marty et al. 2007), or simply generating task sequences (Séjourné et al. 2004). For example Stegmann et al. (2004), developed two scripts, the first aimed at supporting the construction of argumentation sequences and the second at supporting construction of the argument itself. Their results showed that student discourse taking place within scripted collaboration was of higher quality than student discourse without scripted collaboration. In addition, students acquired more individual knowledge. Jermann and Dillenbourg (2003) observed that answering in pairs using ArguGraph (as opposed to answering alone) impacted positively on the elaboration of arguments provided to justify an answer given in a questionnaire. They interpreted this improvement as stemming from the discussion necessary to give a common answer. However, research has shown that discussion alone is not sufficient; conflicts must also be made salient for participants in order to provoke debate (Quignard 2000). In the case of Jermann and Dillenbourg (2003), written answers showed whether individuals' answers were the same or not, but this is not always as simple to decide when a conflict occurs during discussion. In a related aspect of organizing pedagogical sequences, recent research by Veerman et al. (2002) showed that students who prepared more for debate (8 h as opposed to 2), produced Belvedere diagrams during chat interaction that had a higher number of elements that were not in the chat (thus demonstrating higher topic coverage), although the meaning and the argumentative nature of these new elements were not the focus of discussion. Preparation is thus necessary for taking up concepts during debate, but does not guarantee that these concepts are discussed in depth.

This is why specifically organizing the pedagogical sequence to focus on the socio-cognitive conflict(s) is crucial. We mean organizing in terms of specifying the conditions for debate and supporting specific sequences of actions that have the underlying pedagogical goal of obtaining both quality argumentation and knowledge co-construction.

From the short review above, we see that whether or not conceptual conflicts appear in interaction, and whether or not they are cooperatively resolved, can depend on the structure of the CSCL interface, on the organization of pedagogical sequences (*scripting*, building *learning scenarios* or *task sequences*) and on the role different parts of the CSCL system play during different parts of the sequence. Do these parameters facilitate task focus? Are there affordances for the interactive and cognitive mechanisms important for learning?

In the following research, we compare more closely two of the roles defined by De Vries et al. (2002): the computer as a means of representing elements in a discussion and the computer as a medium for communication. This comparison leads us to consider the literature on external representations and learning. We will begin by presenting two examples of how multiple representations affect collaborative learning and then will look at the cognitive mechanisms that are made possible by working individually with multiple representations.

Multiple external representations and collaborative learning

Suthers et al. have focused on the roles of different external representations (diagram, matrices and text) in collaborative problem solving (Suthers 2003; Suthers and Hundhausen 2003). In a comparative experiment, it was shown that pairs of students working side by side on a computer and using an evidential reasoning graph or a matrix for reasoning revisited and re-used information more than pairs of students that used text. Although a matrix was more useful for verifying relations between content, however, some of this verification seemed to be incited by filling in all possible relations appearing in the matrix and not considering the relevance of the content of the relation in the context of the discussion. On the other hand, it seems that a graph helps pairs of students elaborate while keeping them focused.

Van Amelsvoort and Andriessen (2003) have also studied the effects of different types of CSCL representations (text and diagrams). They compared the representations that individual students use for preparation for debate on the quality of those debates. They showed that students discussed more concepts during debate with a partner and wrote more conceptually rich collaborative texts in two conditions out of three. The two conditions that led to higher quality debate and higher quality collaborative text were conditions where the students individually built an argumentation diagram or individually wrote an argumentative text and had the corresponding argumentation diagram built for them, which they subsequently studied before debate. The condition that led to less conceptually rich debate and text was when students wrote an argumentative text before debate.

Producing argumentation diagrams during debate and preparing for debate by producing or studying argumentation diagrams (as opposed to working with text) seems more helpful for producing more conceptually rich argumentation while staying focused on relevant aspects of debate (for characteristics of diagrams, see also Jones et al. 1988; Vézin 1985).

Considering the advantages of argumentation graphs, it is interesting to look more closely at the interactive and cognitive mechanisms that are made possible by them.

From comparing external representations to coordinating and translating between them

The main issue that concerns us here is the transformation of information from one external representation to another and its impact on learning (Duval 1995). Although using multiple representations (diagrams, text, etc.) can lead to more abstract and generalizable knowledge (Ainsworth 1999) and help students memorize information (Molinari and Tapiero 2007), the coordination of or the translation between such representations is more problematic. The larger the differences in the format and operations of two representations (level of abstraction, differences in symbols, strategies that are encouraged, etc.), the more difficult students will find the process of mapping between them (Ainsworth 1997). If learners are familiar with each representation (they understand the format and the operations) and with the domain (they understand the relation between the representation and the domain), then translating between representations, with the help of the underlying domain, should be easier (Ainsworth 1999).

The coordination and translation that is the focus of this article is between a debate in a chat and an argumentation graph. In one condition (Graph for debating), students are asked to use a chat and an argumentation graph in order to debate. In another, students are asked to debate in a chat and then subsequently *represent* their debate in an argumentation graph (Graph for representing a chat debate). In both cases, knowledge construction is taking place through shared representations. In the former, we suppose that two representations are constructed while simultaneously being coordinated, while in the latter, one representation (chat) is translated into another (graph). Although this is the general context of our research, in this article we do not analyze the chat interactions so we cannot directly address the notions of coordination and translation. We do, however, look at the *outcome* of construction coupled with coordination and the *outcome* of translation in terms of how students modify their individual graphs after debate.

To date, there has been no research that compares two specific usages of an argumentation graph in a particular phase of two comparable pedagogical sequences. In our opinion, using an argumentation graph as a tool for representing a debate that has taken place in chat combines the advantages of argumentation graphs per se, and has the potential to capture the benefits of translating between representations. Making a graph out of text involves analyzing and organizing textual information in order to represent it visually. This analysis can be compared to research on text comprehension where a cognitive schema of a text is elaborated by the application of four rules (Kintsch and van Dijk 1978): a rule of selection (take the most important information), a rule of suppression (of detail), a rule of reduction (or generalization) and finally a rule of construction (add new information). The resulting schema should reflect the global structure of the text it represents (in our case, a chat interaction). However, it is not a simple juxtaposition of information; it is a *restructuring* of information that should lead to greater comprehension. The analyses that we carry out in this article take up two of the rules of Kintsch and van Dijk: we consider what type of elements of the individual graph are suppressed or added. In addition, we postulate that although in terms of external representations there are differences between argumentative chat interactions and argumentation graphs (e.g., chronological dialogue vs summarized content and expression of relations), these differences are not considered sufficient for hindering translation. On the contrary, translating from chat to graph could aid in exploring the space of debate. Actively reflecting upon the nature of the connection between two representations (in our case, chat and graph) may lead to the construction of deeper understanding (Ainsworth 1999).

Experimental objectives and method

The objective of our experiment was twofold. First, the teaching sequence was elaborated in collaboration with a classroom teacher in regard to a *pedagogical* objective. Our goal was to help students elaborate knowledge on a particular subject of debate, genetically modified organisms (GMOs), by collaborating within multi-representational (text and diagram) argumentative interactions.

Second, we had a *research and development* objective. Here, our goal was to propose communicative Internet tools for students' argumentative activities and determine to what extent these tools favored such activity. More specifically, we set out to investigate the extent to which two different ways of using the argumentation graph during the debate—

i.e., either as a medium of debate (condition 1) or as a way of representing the chat debate (condition 2)—influence learning. To attain this goal, we measured differences between individual argument graphs obtained before and after the discussion and compared these differences between the two testing conditions (*Graph for debating* condition versus *Graph for representing a chat debate* condition). We were also interested in the potential differences in the collaborative graphs, elaborated during the two conditions.

The Experiment SCALE 2 was carried out over a 4-day period at the end of the school year (May–June 2003). Thirty-six 15–16 year-old students from the Antoine de Saint-Exupéry school for secondary education in France participated as part of class activity. In this section, we begin by presenting DREW (Dialogical Reasoning Educational Webtool), a CSCL Environment designed to promote students' individual and collaborative argumentative activities. We then describe the teaching documents on which students initially worked to refine their own points of view on the subject of the debate (GMOs). Finally, we focus on the specific sequence of tasks carried out by students during this experiment.

The JigaDREW CSCL tool

DREW is a CSCL environment developed in Java by the RIM team of Ecole Nationale Supérieure des Mines de Saint-Étienne (Corbel et al. 2003) within the SCALE project. The DREW system used by the students is composed of tools for communication and collaboration. Figure 1 shows the chat tool and the argument graph editor called JigaDREW (Corbel et al. 2002).

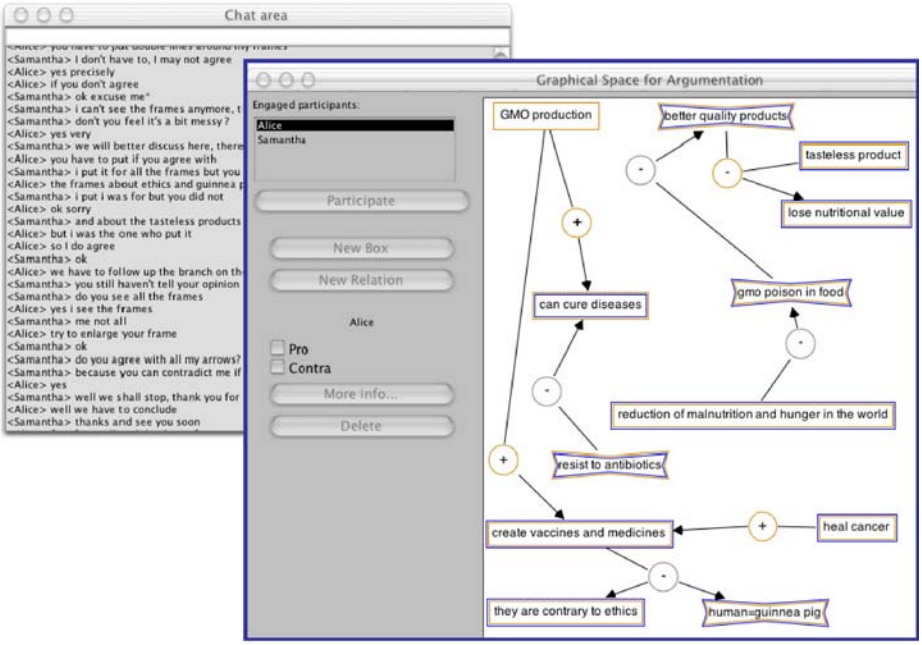

Fig. 1 JigaDREW tool

In the DREW environment, the chat tool (quasi-synchronous written interaction) can be used to debate a subject, to negotiate with others the meaning of elements in the argument graph, or to coordinate a collaboratively written text. The text editor allows students to write, individually or collectively, a synthesis of a text or of a debate they previously conducted. JigaDREW is a shared representational tool that was developed on the basis of the Toulminian graphical structure of argument (Toulmin 1958), with the important added feature that students may take a position in regard to arguments (express an opinion either "for" or "against" an argument or a relation). This makes JigaDREW dialogical (see below), whereas Toulminian graphs are not. JigaDREW can be used either to debate or to represent a debate as a graph composed of theses and arguments (represented by boxes) that can be connected to each other by two types of argumentative links (+ or *in favor* arrows, − or *against* arrows). During the collaborative construction of an argument graph, students also have the possibility of (1) providing comments, and (2) of expressing their own opinions (*in favor* or *against*) for any element of the graph (boxes and arrows). Indeed, each student's opinion appears in a different color, and boxes for which two opposed opinions have been expressed appear in a "crushed" form to represent the conflict.

Task materials

The teaching documents were constructed within a research-action group called PRATIC,[3] whose members included researchers and high school teachers of different disciplines (French, philosophy, civics education). The teachers all taught some aspect of argumentation within their respective curricula and were interested in reflecting on different theories of argumentation and on using the Internet to teach argumentation. The French teacher participated more closely in the design of the teaching documents, as our experiment was carried out in his and his colleague's class and his goal was to use the documents for reviewing the work done on argumentation by his students throughout the year. Work was coordinated with the students' biology teacher, as they had studied questions relating to GMOs.

Three local websites were developed that summarized the viewpoints (as found on their own web pages) of three social actors implicated in the debate on GMOs: (1) Greenpeace (against GMOs), (2) French Research Ministry (neutral in relation to GMOs) and (3) Monsanto (a seed company in favor of GMOs).

Participants and experimental sequence

Thirty-six French secondary school students participated in the experiment during 4 days at the end of the school year. Two sessions were organized according to the two conditions tested: students using the graph to debate and students using the graph as a way of representing their chat debate. The general experimental sequence is shown in Fig. 2.

In a preliminary phase, students were taught elementary notions of argumentation using handouts and the blackboard (day 1). In phase 0, students were trained on the computer-mediated communication tools to be used in phase 2 (day 2). In phase 1, initial acquisition of argumentative knowledge and its structuring was the goal, as students were helped to reflect on their personal opinions in regard to the topic (day 3). In phase 2, it was hoped the

[3] PRATIC stands for "*PRatiques de l'Argumentation avec les Technologies de l'Information et de la Communication*" or Practices in Argumentation with Information and Communication Technologies.

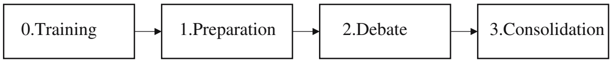

Fig. 2 General experimental sequence

sharing of argumentative knowledge would lead to the co-construction of conceptual understanding and to increased coherence of personal views (day 4). Finally, in phase 3, the objective was that students restructure their personal argumentative knowledge in light of the new arguments and knowledge they gained during the debate phase (also day 4). Table 1 shows the detailed experimental sequence.

Day 1 Notions of argumentation

On day 1, during normal class time (1 h), both groups reviewed some basic notions of argumentation (thesis, argument, contra-argument, elaboration of argument, opinion). Then students were asked to fill in the content of an argument graph that had been constructed from a literary argumentative text they had previously studied (*L'écume des jours*, by Boris Vian, published in 1947). The teacher corrected the exercise on the blackboard and at the end of class, gave the solution to the students on paper.

Day 2 Training with JigaDREW

On day 2 (1 h), students were trained on the practical use of the notions of argumentation they had learned in conjunction with the JigaDREW diagrams. For the first 20 min, each student followed a step-by-step tutorial on how to construct an argument graph. For the next 35 min, student pairs used DREW (chat interface and JigaDREW argument graph) to represent a written dialogue with an argument graph. Finally, each dyad compared their solution with the correct solution, as shown on the computer.

Day 3 Preparation for debate

On day 3, each student first drew an argument graph using his or her own ideas about GMOs (20 min). Second, students browsed the three local websites to get more arguments (20 min). Third, each student modified his or her first graph as a result of the information

Table 1 Detailed experimental sequence

Planning	Phase	Timing	Condition 1 "Graph for debating"	Condition 2 "Graph for representing chat debate"
Day 1	Revision	60 m	Review of argumentation and introduction to argumentation diagrams by the teacher	
Day 2	0. Training	60 m	Integrated training: arguing with diagrams using DREW	
Day 3	1. Preparation	120 m	Students produce an argument graph using his or her own ideas on GMOs. Each student reads web pages on subject to be debated (GMOs). Students modified their individual argument graph on basis of reading	
Day 4	2. Debate	70 m	Graph and chat as medium of debate	Chat as medium of debate
	2.1 Discussion		Flexibly moving from chat to graph as students wish	
	2.2 Synthesis		Synthesis of debate in chat	Joint construction of graph to represent debate in chat followed by synthesis in chat
	3. Consolidation	30 m	Students revise individual graphs in light of their debates	

on the local websites (80 m). Students were allowed to switch back and forth between their graph and the websites.

Day 4 Debate and consolidation

The debate phase was the experimental condition that varied; two different tasks were elaborated: condition 1, where the graph (along with the chat) was the medium of the debate, and condition 2, where the graph was used for representing the debate carried out previously in the chat. We have called condition 1 "Graph for debating" and condition 2 "Graph for representing chat debate".

In the "Graph for debating" condition during the debate phase, students first studied their own individual graph (printed on paper) for about 10 min. Then students debated each other in dyads, using both chat and JigaDREW in the manner they wished (60 min). They were allowed to consult only their own individual graph. Finally, the dyad used chat to synthesize what they had agreed and disagreed on during their debate.

In the "Graph for representing chat debate" condition during the debate phase, students also studied their own individual graph (printed on paper) for 10 min. However, the students debated each other in dyads using only chat for 30 min. Then, for the next 30 min, they used JigaDREW to represent their own chat debate while using the chat interface to manage their interaction. These students also then used the chat interface to synthesize what they had agreed and disagreed on during their debate. As we were in an authentic classroom situation, the teacher constituted the dyads for both conditions, according to pairs of students that had a demonstrated record of working well together. The numbers of students in groups depended on student attendance for that day.

In the consolidation phase, both groups worked individually using JigaDREW to improve their graphs in light of what they experienced during the debate (30 min).

Analyzing argument diagrams: The ADAM method

Rationale

The ADAM (Argumentation Diagram Analysis Method) method was developed by the Lyon team within the SCALE project to determine which of the two tasks we designed favored students' exploration and deepening of their understanding of the question of the debate (Séjourné et al. 2004). We wanted to measure, through analysis of argumentation diagrams, the acquisition of new arguments from a student's partner, the refinement of his or her own understanding as expressed in developed arguments, as well as students' negotiation of the meaning of key concepts in the GMO domain.

Analysis focused on the quality of the student graphs produced before, during and after the debate. Based on our knowledge of the literature on translating between external representations (e.g., Ainsworth 1999), we thought that condition 2 (Graph for representing chat debate) could favor reflection and lead to a better comprehension of the space of debate, as reflected in the argumentative quality of the final graph.

ADAM method

In the ADAM method, the quality of students' argumentation diagrams is measured according to six characteristics:

1. The form of the diagram
2. The quantity of arguments and relations expressed

3. The quantity and nature of opinions expressed
4. The quantity of topics treated within the space of debate
5. The variety and degree of elaboration of the arguments expressed
6. The correctness of argumentative relations.

First, the form of the diagram refers to the type of branching. Either the branches extend in a linear manner from the claim, thus representing elaboration of different arguments, or there is sub-branching, thus signifying that a local thesis (second claim) has developed and that several arguments have been expressed in regard to it. Both types of branching may be present in a single graph.

Second, the number of arguments and relations (links) present in the graph are counted. In addition, it is also possible to add a comment to an argument or to a link; this is also counted. However, there were so few that for this study statistical analyses could not be carried out.

Third, the quantity and nature of opinions expressed refers to the number of opinions that the students express on the graph, as well as whether the opinions are "for" or "against" a given argument.

Fourth, the topics that are broached within the space of debate are counted. Although we will not present results here on these topics, they are Health, Affluence/Welfare, Environment, World-view or Other.

Fifth, the variety of elaboration refers to the extent to which students express all of the main arguments relating to the claim being debated. Degree of elaboration refers to the extent to which students elaborate content. Level 0 is one word (example: GMO). Level 1 is 1 proposition (1 word+1 predicate; e.g., "GMOs are not natural"). Level 2 is 2 propositions (e.g., "GMOs can be dangerous for health in humans"). Level 3 is 2 propositions with an argumentative connector (e.g., "GMOs produce higher yields because they resist insects"). Level 4 is beyond level 3 (e.g., 3 or more propositions or more than one connector, etc.).

Finally, the correctness of argumentative relations refers to whether or not the link expresses argumentative reasoning, e.g., a phrase supporting or attacking a claim rather than something else (a cause for, a consequence of, or an example of a claim or argument). We have taken the position that an argument attacks or supports a thesis. In this way of thinking about argumentation, the arrow goes from an argument to a thesis, or from an argument to another argument (and not from a thesis to an argument, which could nevertheless be understood as "the thesis is supported or attacked by this argument"). Thus, the possible relations are the following:

- Correct direction (link going towards the thesis) and correct sign;
- Correct direction and incorrect sign (+ instead of −; in other words, supporting instead of attacking, for example);
- Incorrect direction and incorrect sign;
- Non-argumentative relation;
- Relation not specified;
- Relation without meaning (two unrelated boxes connected).

The students were taught on day 2 what constituted, in our view, correct direction and sign and they practiced this usage. Given this, only argumentative relations with a correct direction and a correct sign and non-argumentative relations were taken into consideration in the analyses presented in this article.

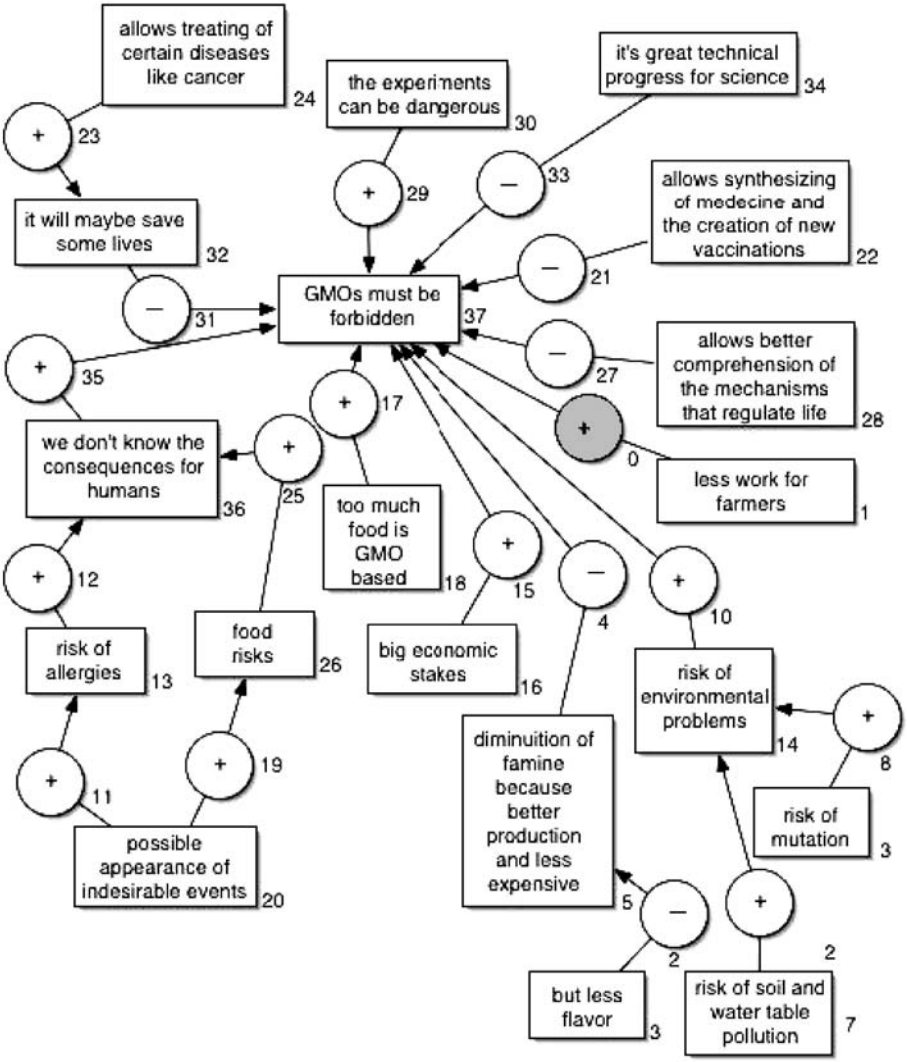

Fig. 3 Example of a student argumentation diagram

Example of ADAM analysis

In this section, the ADAM method will be illustrated by applying it to an example of a student argumentation diagram (Fig. 3, translated from the original French and redrawn, respecting original layout).

1. The form of the diagram;

We begin by locating the main thesis, the question that was to be debated (GMOs must be forbidden).[4] The number of branches from this thesis is 11; there are 4 sub-branches (the

[4] Each student in a pair may choose to express two different theses or a thesis and its negation (in this case, "We must authorize production of GMOs").

boxes from which more than one arrow leaves or enters). The maximum depth is 3 and the visual arrangement is "thesis in the middle," as opposed to "thesis on top."

2. The quantity of arguments and relations expressed;

   There are 18 arguments in the graph (excluding the thesis). There are 19 links.

3. The quantity and nature of opinions expressed;

   There were opinions (agree or disagree) expressed by this student in relation to each and every argument. In addition, this student expressed an opinion in relation to an argumentative relation (the argument "For," labeled n° 0), which is somewhat rare.[5]

4. The quantity of topics treated within the space of debate;

   Arguments having to do with the environment were evoked 4 times (boxes 1, 7, 9 and 14).

   Arguments having to do with health were evoked six times (boxes 13, 22, 24, 26, 32 and 36).

   Arguments having to do with affluence and welfare were evoked five times (boxes 3, 5, 16, 18 and 30).

   Arguments having to do with world-view were evoked two times (boxes 28 and 34).

   The argument "appearance of possible undesirable events" (box 20) was put into the category "other."

5. The variety and degree of elaboration of the arguments expressed;

   Most of the arguments (11) in this student graph are level 2 arguments (2 propositions). There were 11 level 2 arguments (e.g., "allows synthesis of arguments and the creation of vaccinations"), 0 level 3 arguments and 3 level 4 arguments (e.g. "diminution of famine because better production and less expensive").

6. The correctness of argumentative relations.

   Most (14 out of 19) of these students' argumentative links were in the correct direction and had the correct sign. However, two arguments had the correct direction but the wrong sign (link 12 and link 25) and two arguments were in fact non-argumentative relations (link 11 and link 19). There was one relation without significance (link 2).

Results

Data collected during this experiment were as follows: (a) 36 individual argument graphs constructed before the debate; (b) 36 individual argument graphs modified as a function of the debate; (c) 6 collaborative argument graphs constructed in order to debate (condition 1: Graph for debating); and (d) 12 collaborative argument graphs constructed in order to represent the debate (condition 2: Graph for representing chat debate).

Results presented here concern the individual graphs produced before and modified after debate, as well as the collaborative graphs produced during debate. Instructions given to the participants for the use of the collaborative graphs (either for debating or for representing the debate) corresponded to our between-subjects variable. Debate scores—that is, scores relative to collaborative graphs (the number of branches, sub-branches, boxes, positive and negative arrows, argumentative and non-argumentative relations, elements with only one

[5] There is a difference between agreeing or disagreeing with an argument and agreeing or disagreeing with the fact that a statement is in fact an argument for the thesis being debated. In other words, one may agree with a statement, but may not agree that it is *relevant* to the thesis.

opinion or with two opinions, elaboration level of box content) and difference scores (i.e., the modifications from pre- to post-individual graphs in terms of branches, sub-branches, boxes, elaboration level of box content, arrows, positive and negative arrows, argumentative and non-argumentative relations, elements with opinion)—were the initial dependent variables. To conduct appropriate statistical analyses, we reduced the number of dependent variables using the principal component analysis method (see the statistical notes below). Finally, since this experiment was carried out in an exploratory way, we did not have a priori strong predictions concerning the effects of the "instructions factor" on each of the dependent variables retained for the analyses presented in this paper. Having said that, we did hypothesize that translating chat to graph form would promote reflection (as mentioned in the section on ADAM); our objective was to unpack how this could be the case.

In the following subsections, we discuss our approach to the statistical analyses, present results regarding the main variables for studying collaborative and individual graphs, the differences between collaborative graphs constructed for debating (condition 1) or for representing the chat debate (condition 2) and finally the effects of instructions for the use of the collaborative graphs on the modifications of individual graphs.

Statistical notes

All statistical analyses presented here were performed using SPSS Version 12.0.1 for Windows (SPSS Inc, Chicago, IL, USA).

As noted above, a quasi-experimental design was employed. In this study, students were working collaboratively using the DREW platform; hence, there would be possible problems with the lack of independence of post measurements of individuals. As described by Kenny et al. (2006), we checked the non-independence of all difference scores through the computation of intraclass correlations. None of the correlation coefficients reached significance (see Table 2) and this led us to use the individual (instead of the group) as the unit of analysis.

Moreover, since the number of participants was small (36 students in dyads), it was preferable to reduce the number of dependent variables; that is, the number of difference scores and of debate scores. To meet this goal, principal component factor analyses with varimax rotation were performed.

Finally, as MANOVA is sensitive to sample size, we chose to apply either regular one-way ANOVA analyses or non-parametric tests such as Mann-Whitney tests, to examine differences among the two experimental conditions (*Graph for debating* and *Graph for representing the*

Table 2 Intraclass correlation coefficients for difference scores (Differences between pre- and post-individual graphs)

	r	p
Branches	−0.01	0.52
Sub-branches	0.11	0.33
Boxes	−0.20	0.24
Content elaboration	0.17	0.24
Arrows	−0.05	0.58
"+" Arrows	0.32	0.10
"–" Arrows	0.12	0.31
Argumentative relations	0.12	0.32
Non-argumentative relations	0.31	0.10
Elements with opinion	0.03	0.46

chat debate). These comparative statistical analyses were conducted on factor scores that were computed by the factor analysis using the regression method (default method). Non-parametric tests were used when data were not normally distributed (according to the Skewness/Kurtosis tests for normality) or when the variances were unequal (according to the Levene test for homogeneity of variances). The Mann-Whitney test is the non-parametric analog of the unpaired samples *t* test. According to Hart (2001), it can detect differences in shape and spread as well as just differences in medians between two independent groups. Thus, the Mann-Whitney test can be also considered as a test for the difference in means. While the statistical power of ANOVAs diminish with unbalanced groups (in our case, 24 students in dyads in the "Graph for representing the debate" condition and 12 students in dyads in the "Graph for debating" condition), SPSS adjusts automatically for unequal size.

Main factors for studying collaborative and individual argument graphs

As mentioned above, because of the size of participant samples, it was necessary to reduce the number of dependent variables (10 debate scores and ten difference scores). Factor analyses were thus constructed to identify the main factors for analyzing collaborative and individual graphs.

Debate scores were combined using factor analysis. Three independent factors (we named them "argumentation," "opinions" and "explore and deepen" respectively, based on the three argumentative categories of the Rainbow framework (Baker et al. 2002; Baker et al. 2007) were identified that explained 76.49% of the total variance of the entire data set: (1) Factor 1, with an eigenvalue of 4.21, accounted for 42.13% of the variance; (2) Factor 2, with an eigenvalue of 2.18, accounted for 21.78% of the variance; and (3) Factor 3, with an eigenvalue of 1.26, accounted for 12.59% of the variance (see Table 3). Variables that were strongly correlated with Factor 1 (argumentation) were: (a) branches (with a factor loading of 0.86); (b) elaboration level of box content (0.81); (c) boxes (0.79); (d) argumentative relations (0.74); and (e) negative arrows (0.73). Variables that were strongly correlated with Factor 2 (opinions) were: (a) positive arrows (with a factor loading of 0.79); (b) elements

Table 3 Rotated component matrix for debate scores

	Factor 1 argumentation	Factor 2 opinions	Factor 3 explore and deepen
Branches	0.86	−0.20	0.08
Content elaboration	0.81	0.10	0.08
Boxes	0.79	0.30	0.49
Argumentative relations	0.74	0.51	−0.02
Negative arrows	0.73	−0.35	0.42
Positive arrows	0.13	0.79	0.24
Elements with one opinion	0.52	−0.68	0.37
Elements with two opinions	0.03	0.68	0.24
Sub-branches	0.14	0.16	0.91
Non-argumentative relations	0.13	0.15	0.77

with only one opinion (−0.68); and (c) elements with two opinions (0.68). Variables that were strongly correlated with Factor 3 (explore and deepen) were: (a) sub-branches (with a factor loading of 0.91) and (b) non-argumentative relations (0.77). We chose to name these factors according to the categories of the Rainbow framework as they correspond, in general, to the nature of these categories.

Difference scores were also combined using factor analysis. Three independent factors (also named according to the Rainbow categories, i.e. Factor 1: "argumentation"; Factor 2: "opinions"; and Factor 3: "explore and deepen") were identified that explained 73.91% of the total variance (see Table 4). The strength of Factors 1, 2 and 3 varied from the factor analysis performed on debate scores. The most important factor is, this time, Factor 3 (explore and deepen): it had an eigenvalue of 4.38 and accounted for 43.88% of the variance. Variables that were strongly correlated with Factor 3 (explore and deepen) were: (a) non-argumentative relations (with a factor loading of 0.87); (b) elaboration level of box content (0.69); and (c) sub-branches (0.65). Factor 1 (argumentation) and Factor 2 (opinions) accounted, this time, for a smaller percent of the variance (16.01%, with an eigenvalue of 1.60, and 14.02%, with an eigenvalue of 1.40, respectively). Variables that were strongly correlated with Factor 1 (argumentation) were: (a) argumentative relations (with a factor loading of 0.79); (b) branches (0.78); (c) arrows (0.65); (d) boxes (0.62); and (e) positive arrows (0.61). Variables that were strongly correlated with Factor 2 (opinions) were: (a) negative arrows (0.85) and (b) elements with opinion (0.75).

Differences between collaborative graphs constructed for debating or for representing the debate

Since the Levene test showed homogeneity of variances for all factor scores used for studying the 18 collaborative graphs (argumentation—Factor 1: $p=0.43$; "opinions"—Factor 2: $p=0.31$; and "explore and deepen"—Factor 3: $p=0.56$), one-way ANOVA analyses were thus conducted.

Results showed a significant difference between experimental conditions only for "opinions" scores (see Table 5). The large effect size (*Cohen's d*=1.19) indicated that this was a considerable effect.

Table 4 Rotated component matrix for difference scores

	Factor 1 argumentation	Factor 2 opinions	Factor 3 explore and deepen
Branches	0.78	0.23	−0.16
Content elaboration	0.45	0.31	0.69
Boxes	0.62	0.41	0.58
Argumentative relations	0.79	−0.18	0.12
Arrows	0.65	0.40	0.39
Negative arrows	0.26	0.85	0.20
Positive arrows	0.61	−0.24	0.59
Elements with opinion	−0.14	0.75	−0.13
Su-branches	0.10	−0.13	0.65
Non-argumentative relations	−0.20	0.08	0.87

Table 5 Differences between collaborative graphs constructed either for debating or for representing their chat debate: Results of ANOVAs

	MS	*F*	*p*	Effect size d	Power (1-ß error prob.)
Factor 1 argumentation	0.61	0.60	0.45	0.40	0.66
Factor 2 opinions	5.01	6.69	0.02	1.19	0.86
Factor 3 explore and deepen	0.004	0.004	0.95	0.02	0.51

As illustrated in Table 6, there were more elements (boxes and arrows) for which both partners expressed their own opinions (*in favor* or *against*) in the collaborative graphs when they were constructed for debating rather than for representing the debate. A supplemental Mann-Whitney test showed that this difference was significant ($U=11.00$, $z=-2.51$, $p=0.012$). Although differences in means were observed for "elements with one opinion" (i.e., more elements for which only one student expressed his/her opinion in the collaborative graphs constructed for representing the debate) and "positive arrows" (i.e., more positive arrows between boxes in the collaborative graphs constructed for debating), these differences were not significant: $F(1, 16)=0.58$, $p=0.46$, and $F(1, 16)=3.93$, $p=0.07$), respectively.

Effects of instructions for the use of collaborative graphs on the modifications of individual graphs

One-way ANOVAs were performed on "argumentation" (Factor 1) and "opinions" (Factor 2) scores (Levene tests for homogeneity of variances: $p=0.34$ and $p=0.17$, respectively), but results did not show any significant differences between experimental conditions (see Table 7).

A non-parametric Mann-Whitney test was performed on "explore and deepen" (Factor 3) scores because the Levene test showed non-homogeneity of variances ($p=0.007$). Results from this test showed a significant difference between conditions ($U=66.00$, $z=-2.62$, $p=0.009$). As depicted in Table 8, the number of non-argumentative relations in the post-individual graphs (a) increased for participants who were instructed to construct the collab-

Table 6 Means and standard deviations of debate scores for collaborative graphs constructed either for debating or for representing their chat debate

		Graphs for representing the debate ($n=12$)		Graphs for debating ($n=6$)	
		M	SD	*M*	SD
Factor 1 argumentation	Branches	5.75	2.93	7.17	3.19
	Content elaboration	24.08	13.41	27.83	11.89
	Boxes	12.25	4.65	14.67	3.98
	Argumentative relations	7.58	3.23	9.67	2.58
	Negative arrows	5.67	5.28	5.17	1.60
Factor 2 opinions	Positive arrows	5.67	2.84	8.83	3.87
	Elements with one opinion	6.75	8.40	3.83	5.71
	Elements with two opinions	1.33	3.42	12.33	10.13
Factor 3 explore and deepen	Sub-branches	1.08	1.24	2.00	2.00
	Non-argumentative relations	2.25	1.82	1.67	1.75

Table 7 Effects of instructions for the use of the collaborative graphs (either for debating or for representing their chat debate) on the post-individual graphs: Results of ANOVAs

	MS	*F*	*p*	Effect size d	Power (1-ß error prob.)
Factor 2 “argumentation”	0.005	0.005	0.94	0.03	0.51
Factor 3 “opinions”	0.03	0.03	0.86	0.06	0.53

orative graph for representing their chat debate, and (b) decreased for participants who were asked to debate each other using JigaDREW. A supplemental one-way ANOVA test showed that this difference was significant, $F(1, 34)=5.48$, $p=0.02$, with an effect size of .89 and a respectable power of .95. The same pattern occurred for the number of sub-branches in the post-individual graphs, but a Mann-Whitney test did not show a significant difference between conditions ($U=97.00$, $z=-1.81$, $p=0.07$). Finally, in the post-individual graphs, the increase in the elaboration level of box content was approximately the same in the two conditions ($F(1, 34)=0.16$, $p=0.70$).

In sum, two results can be pointed out. First, the main difference between the two types of collaborative graphs—that is, graphs for debating and graphs for representing the chat debate—concerns the argumentative activity of expressing opinions. Students who are instructed to represent their chat debate in an argument graph are less inclined to state their respective opinions in regard to the same elements (arguments or relations between arguments) of their collaborative graph. Secondly, the instruction given to the participants regarding the use of the argument graph during the collaborative phase (either for debating or for representing their chat debate) has a significant impact on the modifications of pre-individual graphs, and this impact mainly concerns the argumentative activity of exploring and deepening. In the individual graphs, revised after the collaborative phase, non-argumentative relations are added by participants assigned to the “Graph for representing the chat debate” condition, whereas the participants assigned to the “Graph for debating” condition suppress some of these relations. As presented in the section on the ADAM method, non-argumentative relations are usually used to link an argument box with an explanation/elaboration box (or with a chain of explanation/elaboration boxes).

Table 8 Means and standard deviations of difference scores for participants instructed to construct the collaborative graph either for debating or for representing their chat debate

		Graphs for representing the debate (n=24)		Graphs for debating (n=12)	
		M	SD	*M*	SD
Factor 1 explore and deepen	Non-argumentative relations	0.58	1.28	−0.33	0.65
	Content elaboration	3.92	5.32	3.25	3.33
	Sub-branches	0.42	0.88	−0.08	0.52
Factor 2 argumentation	Argumentative relations	1.79	2.27	1.33	1.78
	Branches	0.50	1.14	0.67	0.89
	Arrows	2.21	2.06	1.25	1.49
	Boxes	2.13	1.78	1.17	1.40
	Positive arrows	1.17	1.66	0.83	1.19
Factor 3 opinions	Negative arrows	1.04	1.40	0.42	0.99
	Elements with opinion	4.88	8.07	7.00	6.56

Conclusion

In this article, we sought to compare the influence of two types of instruction for using an argumentation diagram during pedagogical debates over the Internet on student collaboration and on individual student argumentation diagrams. More specifically, we studied how using an argumentation diagram as a medium of student debate (Graph for debating) and using an argumentation diagram as a way of representing student's chat debate (Graph for representing a chat debate) influenced two phenomena. We first looked at the modifications that students made to individual graphs after debating with one of these conditions, and second, we looked at how each condition influenced their collaboration in terms of the type of graph they constructed during debate.

The instruction given for using the argument graph during the collaborative phase has a significant impact on the modification of individual graphs insofar as a particular aspect of "exploring and deepening" arguments is concerned. Students in the "Graph for representing the chat debate" added more non-argumentative relations. We call these relations non-argumentative per se, as they are not direct arguments for or against theses or other arguments. Rather, they are causes, consequences and examples; semantic relations between content that strongly support argumentative reasoning. It seems that asking students to construct a collaborative graph for representing their debate, in other words *transforming* argumentative knowledge from chat to graph, led them to deepen their conceptual understanding of the debate topic. However, in order to verify if this type of restructuring increases conceptual understanding, it would have been helpful to engage students in another learning situation where they would have been asked to reinvest their understanding of the debate topic, such as in a synthesis task.

In terms of mobilizing argumentative knowledge, there were two major distinctions between instructing students to use a "Graph for debating" or a "Graph for representing a chat debate," concerning their collaboration. For one, the latter had the effect of causing students to be less inclined to take positions together with regard to the same elements of their collaborative graph (arguments or relations between arguments). While the graph for debating may be a representation of where each partner's individual perspectives are confronted with one another, it seems that the graph for representing the chat debate is a representation of a unique voice, that of the members of the group. This representation reflects a shared perspective, stemming from consensus. It may also be easier to neglect assigning an opinion to each argument when a debate is being transposed from chat to graph (Graph for representing chat debate), while the "Graph for debating" condition allows for expression of opinions as arguments are being formed. It's important for students to distinguish between an argument and an opinion in regard to that argument in order to understand that different social actors may hold different opinions on the same argumentative content. For example, greenpeace is against the argument "GMOs are not dangerous for the environment," while the Monsanto seed company is in favor of it. The fact that the "Graph for debating" condition had the effect of causing students to add more opinions to their collaborative graph could be explained by the fact that during debate, students obtained arguments they knew they did not agree with and were more able to distinguish between argument and opinion than those students preoccupied with representing their chat debate with the graph. Indeed, JigaDREW allowed for explicit expression of being for or against a particular argument and it may be that marking one's opinion is easier "on the fly" (Graph for debating) than when painstakingly locating and transposing arguments from chat to graph form (Graph for representing chat debate).

In conclusion, in a pedagogical sequence where students produce an individual argument graph, then debate, and finally revise their individual argument graph, changing how students are instructed to use an argumentation graph during debate does have an impact on (1) their collaboration and (2) how they revise their individual argument graphs. *Translating* between two external representations of argumentation (from a debate in chat to an argument graph) is beneficial for elaborating argument content. However, students could potentially use help in distinguishing between elaborations that are directly argumentative (more complex predicates for a given argument and justifications/warrants for arguments in the Toulminian sense) and those elaborations that more generally support argumentative discourse (examples, causes and consequences of arguments). On the other hand, using a graph as a medium for debate (*coordinating* between chat and graph while constructing) increases expression of opinion about arguments (*for* or *against*) during collaborative activity. Thus, coordinating between two external representations and translating one into another bring about different cognitive and interactive mechanisms. In other words, argumentation is transformed by technical and psychological tool use, as is the tool use transformed by how students argue.

These results inform us as to the design of CSCL systems focused on argumentation and the learning situations in which they are embedded. How an argumentation graph is used and the pedagogical context in which it is placed can be chosen as a function of specific learning goals in relation to the elaboration of argumentative knowledge. The ADAM method allowed us to understand how the participants constructed and re-constructed their graphs and to a certain degree to understand the content level of the arguments. However, this method does not include a deep content analysis of arguments nor does it allow us to take into account the interaction occurring during construction of the collaborative graph.

Further work will focus on aiding the translation from one external representation to another (chat to graph), on relating an ADAM analysis to an analysis of the chat interactions, and will address the potential roles of teachers during this process.

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