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Coordination processes in computer supported collaborative writing

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Abstract

In the COSAR-project a computer-supported collaborative learning environment enables students to collaborate in writing an argumentative essay. The TC3 groupware environment (TC3: Text Composer, Computer supported and Collaborative) offers access to relevant information sources, a private notepad, a chat facility including a chat history, and a shared word-processor. Planning tools for writing – a shared argumentation diagram for content generation and a shared outline facility for content linearization – were added to the basic TC3 environment. About 145 pairs of high school students completed essays on organ donation or cloning in the TC3 environment. We analyzed the logged discussion ('chats') and activity protocols for task-related processes present during discussion and collaboration. Processes looked into are planning, gathering information and composing the essay, as well as collaborative processes such as coordinating, turn taking and time management. Our main research question is how task-related planning activities and collaborative coordination with or without the help of planning tools relate to the quality of the resulting argumentative texts. Overall coordination and planning of the writing activities on a meta-level and on a content level were found to be crucial for the quality of the text.

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1. Coordination processes in computer supported collaborative writing

A recent Dutch educational law has transformed the curriculum in the last three years of college preparatory high school. Among the changes, schools are required to provide support for students to do increasingly independent research, in order to prepare them better for college studies. Working and learning actively, constructively and collaboratively are seen as important parts of this program called "study-house". The computer-supported, collaborative writing environment that is used in this research is meant to fit within this new curriculum. As a *groupware* environment it can emphasize both the constructivist and collaborative aspects because of its active and interactive nature.

Computer Supported Collaborative Learning (CSCL) systems are assumed to have the potential to enhance the effectiveness of peer learning interactions (Andriessen, Erkens, Overeem, & Jaspers, 1996; Bannon, 1995; Dillenbourg, 1999; Katz, 1995). Groupware programs are used for CSCL as they generally support and integrate two functions: task support and communicative support. They are meant to support collaborative group work by sharing tools and resources between group members and by giving communication opportunities within the group and to the external world. So in groupware programs computer supported tools are generally of two kinds: task related and communicative. Task-related tools support the performance of the task and the problem-solving process. Communicative tools provide access to collaborating partners, but also to other resources like external experts or other information sources via the Internet. The function of the program is, in this respect, a communication medium (Henri, 1995). The task related aspect is mainly realized by offering computerized tools that can be helpful for collaborating students in solving the task at hand (e.g., the CSILE-program of Scardamalia, Bereiter, & Lamon, 1994; the Belvedere program of Suthers, Weiner, Connelly, & Paolucci, 1995). Tools in a groupware environment are shared and accessible to all participants. In this way they can not only support task related constructive activities, but also the collaborative deliberation about these activities. The basic components in a powerful CSCL groupware environment are the tasks and activities, the learning resources and the shared tools that support the collaborative performance of the task. The purpose of this study is to investigate the effect of the developed computer supported writing environment and its planning tools on the final written product through differences in the participants' collaboration processes. Our main research question then is how support of task-related planning activities and collaborative coordination relate to the quality of the resulting argumentative texts.

2. Planning in collaborative argumentative writing

Writing argumentative texts of any length is a complex process consisting of several interrelated sub processes, each with its own dynamics and constraints (Alamargot & Chanquoy, 2001; Rijlaarsdam & van den Bergh, 1996). This task requires that

information is generated, collected, selected, related, and organized into a consistent knowledge structure. In addition, the writer must find a persuasive line of argumentation to convince the reader. For successful completion of the task social, cognitive, rhetorical, and cultural skills are called on.

Theories of writing (Hayes & Flower, 1980; Hayes & Nash, 1996) generally distinguish three types of activities within the writing process: planning (generating, organizing and linearizing content), formulating or translating (writing the text), and revising. For planning an argumentative text, arguments need to be generated and ordered based on ones position and the demands of the audience. Unlike in storytelling, the order of the content of an argumentative text does not inherently follow from the order in which events take place (McCutchen, 1987). During planning activities, ideas will probably be conceived and organized from a perspective other than time – for instance, in argument clusters. The contents need to be linearized (ordered) before the ideas can be rendered into text, and again when the contents are reorganized. Linearization, therefore, is an important activity in argumentative writing (Levelt, 1989). Converting the conceptual representation of ideas into linear text appears to be a crucial problem for the novice writer of argumentative texts (Coirier, Andriessen, & Chanquoy, 1999).

The main advantage of collaborative writing, when compared to individual writing, is the possibility of receiving and giving immediate feedback. According to Stein, Bernas, and Calicchia (1997), argumentation itself facilitates learning because it necessitates searching for relevant information and using each other as a source of knowledge. In addition, the discussions generated by the argumentation task make the collaborators verbalize and negotiate, among others, purpose, plans, concepts, and doubts. Collaborating writers need to test their hypotheses, justify their propositions, and clarify their goals. This may lead to increased awareness of and more conscious control over the writing and learning processes (Gere & Stevens, 1989; Giroud, 1999).

In collaborative writing, reflecting on planning becomes a natural process, because by writing a shared text, the partners will have to agree on both the content and the organization of the text. In addition, the use of sources needs to be coordinated and discussed. Thus, the constructive activities of organizing, linearizing as well as translating to the common text have to take place in mutual deliberation, necessitating verbalization and reification of ideas. This negotiation, leading to shared knowledge construction, takes place in the collaboration dialogue between the partners (Erkens, Andriessen, & Peters, 2003). We expect to find that more mutual coordinating activities in the dialogue result in a more consistent shared knowledge structure, and in a better mutual problem solution, that is, a better argumentative text (see also Baker, 1999). Furthermore, support of content generation, organizing and linearization should make these planning activities explicit and negotiable. The groupware computer environment that has been developed in the COSAR research project (COSAR stands for 'Computer Support for Collaborative and Argumentative Writing') attempts to support students during planning by providing specific tools for conceptual generation, organization and linearization and by offering help on using these planning tools.

3. Coordination processes

A collaborative learning situation may be defined as one in which two or more students work together to fulfill an assigned task within a particular domain of learning in order to achieve a joint goal (Cohen, 1994). The collaborating partners must have a common interest in solving the problem at hand. Furthermore, they should be mutually dependent on the information, resources, tools and cooperative intention or willingness of the partners to reach their common goals. Under these conditions of mutuality, coordination of task strategy and the constructive activities to achieve a shared understanding of the problem are crucial aspects of collaborative learning. In earlier research we found that this coordination is realized by a complex interaction between task related strategies, cooperative intentions and communication processes during collaboration. In the collaborative learning situation the learning results will be influenced by the type of task, the composition of the group, the complementarity in expertise of the participants, the resources and tools available, and the educational climate. In order to achieve the common goal the collaboration partners will have to coordinate their activities and their thinking. They will have to activate their knowledge and skills and will have to establish a common frame of reference in order to be able to negotiate and communicate individual viewpoints and inferences. Furthermore, shared understanding of the problem at hand – a joint problem space (Roschelle & Teasley, 1995) – or a collective landscape of concepts (Erkens et al., 2003) must be constructed and a problem solving strategy has to be agreed upon. In this way the collaborative learning situation stimulates three main processes of coordination: (1) mutual activation and sharing of knowledge and skills, (2) grounding or creating a common frame of reference, and (3) negotiation or the process of coming to agreement. Specific activities can be distinguished within these three processes: focusing, checking and argumentation.

By focusing, students try to maintain a shared topic of discourse and to repair a common focus if they notice a focus divergence. Students coordinate their topic of discourse by focusing. By checking new information (from an external source or from the partner) with regard to the knowledge that was (co-)constructed, the students guard the coherence and consistency of their collective knowledge base. By checking, students ground their communication in a common understanding (Clark & Brennan, 1991). In earlier research checking was found to be one of the major coordinating activities in dialogues of collaborative problem solving and related to the quality of the problem solving process (Van der Linden, Erkens, Schmidt, & Renshaw, 2000). Moreover, the participants also need to come to agreement with respect to task strategies, relevant concepts and relationships. By argumentation they will try to change their partner's viewpoint to arrive at the best way to solve the task at hand or at a definition of concepts acceptable for all. In this argumentation process they try to convince the other(s) by elaborating on their point of view, giving explanations, justifications and accounts (Antaki, 1994). A process of explicit argumentation should lead to agreement on the task strategies to be followed and on the inferences to be drawn (Baker, 1999).

Alternatives need to be deliberated and compared to each other, and a joint decision has to be made on which alternative to use (Di Eugenio, Jordan, Thomason, & Moore, 2000).

4. Research questions

1. How does support of organization and linearization relate to the quality and coherence of the collaboratively written essays?
2. How do planning tools for generating, organizing and linearizing arguments moderate writing activities like planning, translating and revising, in different phases of argumentative writing?
3. How do features of the planning process (generating, organization and linearization) and the ICT tools relate to the coordination in the dialogue of collaborating students in terms of checking, focusing and argumentation?

5. The TC3 environment

A groupware environment called TC3 (Text Composer, Computer supported and Collaborative) was developed with which pairs of students can write argumentative essays collaboratively (Erkens, Prangsma, Jaspers, & Kanselaar, 2002). This environment combines a shared word processor, a chat facility, and access to a private notepad and online information sources. Each partner works at his/her own computer, and wherever possible partners were assigned to different classrooms. The basic TC3 environment, shown in Fig. 1, contains four main windows of which the upper two windows are private and the lower two windows are shared:

1. INFORMATION (upper right window): This private window contains tabs for the assignment (''i''), sources (''bron'') and TC3 operating instructions (''handleiding''). Sources are divided evenly between the students. Each partner has 3 or 5 different sources plus one – fairly factual – common source. The content of the sources cannot be copied or pasted.
2. NOTES (upper left window, ''AANTEKENINGEN''): A private notepad where the student can make non-shared notes.
3. CHAT (lower left, 3 small windows): The student adds his/her chat message in the bottom box. Every letter typed is immediately sent to the partner via the network, so that both boxes are WYSIWIS: What You See Is What I See. The middle box shows the incoming messages from the partner. The scrollable upper chat box contains the discussion history.
4. SHARED TEXT (lower right window, ''GEMEENSCHAPPELIJKE TEKST''): A simple word processor (also WYSIWIS) in which the shared text is written while taking turns.

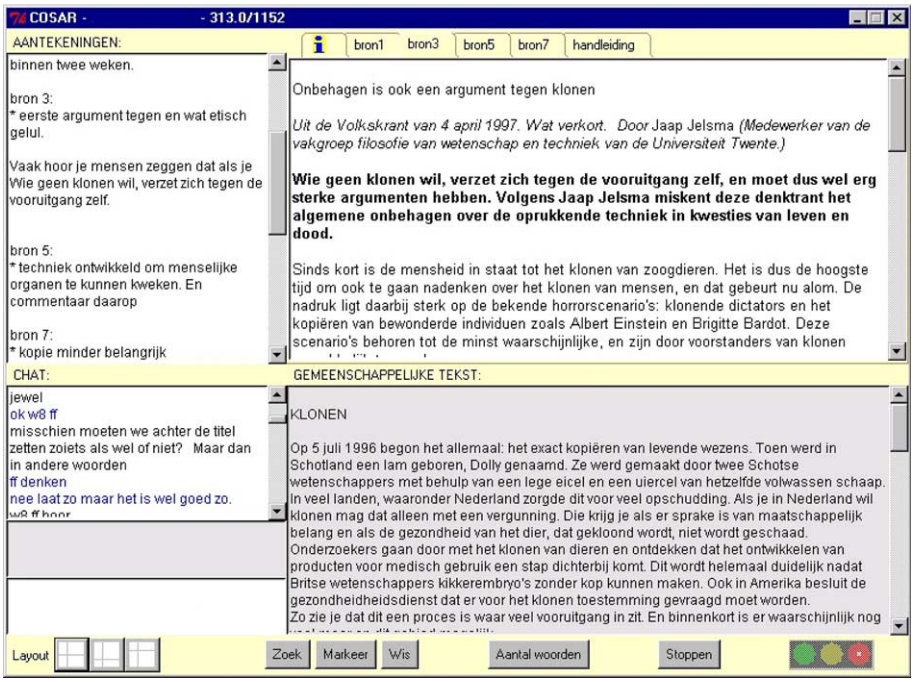

Fig. 1. The interface of the basic TC3 environment.

Text from the private notes, chat, chat history and shared text can be exchanged through standard copy and paste functions. The buttons search (“zoek”), mark (“markeer”), and delete (“wis”) can be used to mark and unmark text in the source windows and to search through the marked texts. The number of words (“aantal woorden”) button allows the participants to count the number of words in the shared text editor at any given moment. The stop (“stoppen”) button ends the session. The traffic light button serves as the turn taking device necessary to take turns in writing in the shared text editor.

In addition, two planning tools and a supporting facility were developed in the TC3 program for the experimental conditions: the Diagram, the Outline and the Advisor. The Diagram (see Fig. 2) is a shared tool for generating, organizing and relating information units in a graphical knowledge structure comparable to Belvédère (Suthers & Hundhausen, 2001; Suthers et al., 1995). The tool was conceptualized to the students as a graphical summary of the information in the argumentative essay. Students were instructed that the information contained in the diagram had to faithfully represent the information in the final version of their essay. This requirement was meant to help students to notice inconsistencies, gaps, and other imperfections in their texts, and encourage them to review and revise. In the Diagram, several types of text boxes can be used: information (“informatie”), position (“standpunt”), argument pro (“voorargument”), support (“onderbou-

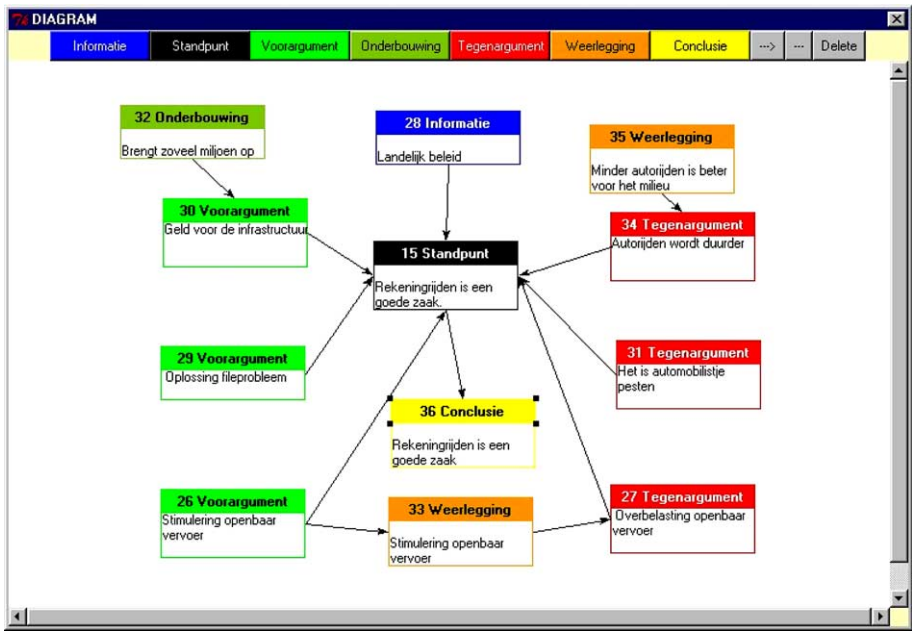

Fig. 2. The diagram window in the TC3 program.

wing''), argument contra (''tegenargument''), refutation (''weerlegging''), and conclusion (''conclusie''). Two types of connectors were available to link the text boxes: arrows and lines. The Diagram can be used to visualize the argumentative structure of the position taken by the students.

The Outline (see Fig. 3) is a shared tool in the TC3 program for generating and organizing information units as an outline of consecutive subjects in the text. This tool was conceptualized to the students as producing a meaningful outline of the paper, and as for the Diagram, the participants were required to have the information in the Outline faithfully represent the information of the final text. The Outline tool was designed to support planning and organization of the linear structure of the texts. The tool allows students to make an overview or hierarchical structure of the text to be written. This should help them in determining the order of content in the text. In addition, the Outline tool has the didactic function of making the user aware of characteristics of good textual structure, thus allowing the user to learn to write better texts. The Outline has a maximum of four automatically indented, numbered levels. Both planning windows are WYSIWIS.

The Advisor is a help facility that provides advise on how to use the Diagram and/or Outline. The Advisor consists of a tab sheet added to the information window with tips and instructions for optimum use of the planning tools: the Diagram or the Outline.

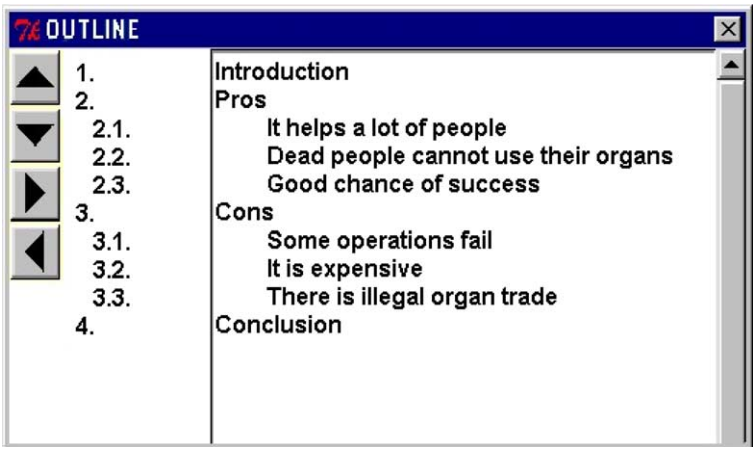

Fig. 3. The outline window in the TC3 program.

6. Method

6.1. Design

For answering the research questions about the relation of using the shared planning tools and task and communicative coordination processes, an experiment was set up. The experiment was executed in two in time separated studies: the first year the control group and the second year the experimental groups. The control condition refers to the basic TC3 environment, whereas the planning tools and advising facility were experimentally varied, resulting in seven experimental conditions (see Table 1).

Participants in the Advisor condition received extra instructions before writing about generating, organizing and linearizing ideas in writing an argumentative text. Furthermore, they had access to the Advisor facility in the program with tips and hints for the planning tool they were able to use. To control for school effects, classes from different schools were assigned to each condition. To control for differences in writing and argumentation skills two pre-tests were administered before executing the collaborative writing task. No systematic differences between students from different school classes were found in writing or argumentative competencies.

6.2. Participants

Participants were 290 Dutch students aged 16–18 from six secondary schools in the Netherlands. The assignment was completed during four to six lessons. The analyzed samples included 151 girls and 139 boys. The students from a class worked in pairs that were put together randomly. Pairs were assigned by the experimenter on the basis of the list of names provided by the teacher. Mixed gender dyads comprised 58 pairs of the total sample, while 46 dyads were all female, and 41 were all male.

Table 1
Experimental design

Abbrevation	Condition	Tools and facilities
C	Control	Basic TC3
D	Diagram	Basic TC3 + Diagram
DA	Diagram Advisor	Basic TC3 + Diagram + Advisor
DO	Diagram Outline	Basic TC3 + Diagram + Outline
DOA	Diagram Outline Advisor	Basic TC3 + Diagram + Outline + Advisor
O	Outline	Basic TC3 + Outline
OA	Outline Advisor	Basic TC3 + Outline + Advisor

6.3. Analysis of the essays

The collaborative writing task the students had to fulfill was to write an argumentative text of 600–1000 words in Dutch on cloning or organ donation. The assignment was to convince the Minister of Health, Welfare and Sport of the position the students choose to defend on the issue. The arguments pro or con the position had to be based upon facts and discussions about the issue presented in external information sources. The sources were taken from the Internet sites of Dutch newspapers. By splitting the sources among the partners, the students had to exchange and discuss the relevance of the information presented in the sources. In all groups, partners were seated in separate computer rooms, to encourage them to communicate only through TC3. Naturally, communication during breaks and in between sessions could not be prevented. The students received teacher grades for their texts as part of their normal Dutch language curriculum.

Each of the 145 student pairs produced one essay, and this was analyzed on several dimensions. Before coding, the experimenters manually divided the texts into segments, largely based on the existing paragraph structure. The texts were scored on four variables:

1. Textual structure, formally defined by introduction, body, and conclusion;
2. Segment argumentation: argumentative quality of the paragraphs;
3. Overall argumentation: the quality of the main line of argumentation in the text, and
4. Audience focus: the presentation towards the reader and the level of formality of the text.

The interrater reliability for these measures was very high, with correlations between two independent raters for the five text scores on five texts ranging from 0.71 to 1.00 ($p < 0.01$).

6.4. Analyses of the chats

All communication and activities of the participating students during the collaboration in the TC3 groupware environment are logged automatically in a chat and

activity protocol. The chat discussions between the students were analyzed by coding episodes with regard to topic of activity (Task act) and communicative coordination processes (Coordination process). The program Multiple Episode Protocol Analysis (MEPA) was used to analyze all the data the students produced in the TC3 environment. The purpose of MEPA [1] is to offer a flexible computer supported environment for creating protocols from verbal and non-verbal observational data, and annotating, coding and analyzing these data. Task act and coordination process coding was done with the aid of the MEPA program.

6.5. Planning and executing through Task acts

As the only means of direct communication between the collaborating participants is the chat facility, the data captured in this window will no doubt contain valuable information about the writing process and the collaboration between the students. In addition to text content, the participants also discuss their writing strategies, such as planning and revision. This category of information was conceptualized as consisting of Task acts.

The Task act coding system of Breetvelt (1991), and indirectly of Hayes and Flower (1980), forms the basis of our system of analysis. We adapted the framework for analysis of collaborative data, as these models were originally intended for analysis of writing tasks for individuals. We had to take into account the influence of social communicative and coordinating aspects of the discussion: collaborating students do not just communicate task related information, but also try to get to know each other better and exchange non-task related information. In addition, our participants had to negotiate turn taking. The protocols were manually divided into episodes of different Task act categories. Whenever the focus of the discussion changed within a particular type of Task act, a new episode was started as well. The Task acts were subdivided into three main categories:

- the Planning level,
- the Executing level,
- the Non-task level.

The three levels were further divided into 24 categories: 12 for planning, 10 for executing, and 2 for non-task. The categories are described in Table 2. Task acts at the Planning level refer to all utterances in which participants plan, propose or discuss future actions with regard to writing the text. In general, then, the planning level refers to meta-cognitive writing strategies. Task acts at the Executing level are all utterances that are concerned with specific contents of writing. At the Non-task level, chat on technical aspects of the program is distinguished from socially oriented chat. Reliability analyses showed the Task act coding to be relatively reliable with Cohen's

[1] MEPA was developed as a general program for protocol analysis and is being used in several research projects at Utrecht University, as well as abroad. For further information, please contact G. Erkens (g.erkens@fss.uu.nl).

Kappas between 0.57 and 0.64 and an interrater agreement percentage between 61% and 69%.

In order to investigate the dynamics of collaborative argumentative writing the protocols were divided in three phases: (1) the period before actually writing the first draft, (2) the first half of the actual writing period, and (3) the second half of the actual writing period.

6.6. Coordinating through Dialogue acts

The utterances in the chat discussions were also coded on the type of discourse act (Dialogue act) that is used. The Dialogue act coding indicates the communicative function of an utterance. The Dialogue acts were mainly derived from discourse markers. Discourse markers are characteristic words showing the function of the phrase in a dialogue (Schiffrin, 1987). The coding system distinguishes between five communicative functions: argumentative, responsive, informative, elicitative, and

Table 2
Task act definitions: planning, executing and non-task levels

Category	Description
Planning level	
1. Plan-turn alternation	Coordinating turn taking.
2. Plan-coordination	Planning time and activities of interaction without going into detail.
3. Plan-Diagram	Coordinating the use of the Diagram and asking for general feedback.
4. Plan-external source	Planning the use of sources not given within TC3, without going into detail.
5. Plan-goals	Discussing the task demands and goals.
6. Plan-knowledge	Planning personal knowledge or opinions not stated in the sources.
7. Plan-layout	Planning the layout of the argumentative text.
8. Plan-notes	Planning and coordinating note taking without going into detail.
9. Plan-Outline	Coordinating the use of the Outline and asking for general feedback.
10. Plan-revision	Proposing and coordinating revision of the shared text.
11. Plan-source	Planning the use of sources (assignment and information sources).
12. Plan-text	Planning the main outline of the shared text without going into detail.
Executing level	
1. Execute-word count	Counting the number of words in the shared text.
2. Execute-Diagram	Discussing specific contents of the Diagram.
3. Execute-external source	Discussing specific contents of external sources.
4. Execute-goals	Discussing the demands and goals for the contents of the shared text.
5. Execute-knowledge	Discussing specific contents of knowledge/experiences not in the sources.
6. Execute-notes	Discussing specific contents of notes taken.
7. Execute-Outline	Discussing specific contents of the Outline.
8. Execute-revision	Discussing and executing revision of specific parts of the text.
9. Execute-source	Discussing specific contents of sources.
10. Execute-text	Discussing specific text and asking for feedback on shared text contributions.
Non-task level	
1. Non-task program	Discussing technical aspects of TC3 and use of the program.
2. Non-task social	Discussing Non-task matters, mainly social talk.

imperative utterances. These five types of communicative functions can be further subdivided into 30 different Dialogue acts.

Argumentatives are utterances indicating a line of argumentation or reasoning. Reasoning is used to clarify, to conclude or to explain, but also to convince the partner. *Responsives* are mostly answers to questions and proposals, but they can also be positive, neutral or negative reactions to other utterances from the partner. *Informatives* serve to transfer information. Information can be transferred through a statement or an evaluation. *Elicitatives* are (open or closed) questions or proposals requiring a response. *Imperatives* are commanding utterances. We distinguished between two types of imperatives: commands to take action and remarks to draw the attention of the partner.

The Dialogue act coding of the protocols was mainly done automatically with the help of the MEPA program. In the program a filter file was created that could categorize the chat utterances with the Dialogue acts. A filter is a set of if-then rules that use pattern matching to look for typical words or phrases. For example, if a line in the chat protocol contains the word *because*, then it should be coded as 'argumentative reason'. The filter file for the Dialogue acts contained more than 700 of these if-then rules. With the filters, some 80–85% of the protocol lines were coded automatically. The remaining lines were coded as informative statements and checked manually. A random check by a linguist and an educational scientist showed that over 90% of each protocol was coded correctly by the filters. The reliability of the automatic coding filters is naturally high, but the manual correction makes the procedure slightly less reliable.

Focusing, checking and argumentation cannot be observed directly: these processes of coordination are measured through indicators, represented by specific Dialogue acts. These Dialogue acts possibly indicate when a coordination process is in progress. The variables focusing, checking, and argumentation were obtained by adding up the percentages for the indicators in the chat protocol. Focusing is indicated by proposals for action, open questions, and imperatives as these generally specify the topics of discourse. Checking is indicated by verifying and other closed questions, and all types of confirming, accepting or denying responsives. Argumentation is indicated by the use of argumentatives. The indicators are show in Table 3.

Table 3
Indicators for focusing, checking, and argumentation coordination processes

Focusing	Checking	Argumentation
Elicitative proposal for action	Elicitative question verify	Argumentative reason
Elicitative question open	Elicitative question set	Argumentative contra
Imperative action	Responsive confirm	Argumentative conditional
Imperative focus	Responsive deny	Argumentative then
	Responsive accept	Argumentative disjunctive
		Argumentative conclusion

7. Results

7.1. Tool condition and quality of texts

In order to answer the first research question, the tool conditions in relation with the quality of the essays will be discussed. Table 4 shows the means and standard deviations of quality scores of the argumentative texts for all conditions separately and for the sample as a whole.

Table 4 shows that the scores were quite similar for all groups. Independent samples *t*-tests showed no differences between the two topics – organ donation and cloning – and there were no significant gender differences (between female, male or mixed groups) either. The quality of the texts was not very high: an average of 6.2 on a scale of 1–10 is not very impressive. We found a few differences in a multiple comparison analysis on the conditions: the Diagram–Advisor group had slightly lower scores on textual structure and segment argumentation, especially in comparison with the Control, the Diagram, and the Diagram–Outline–Advisor condition. In general we can say that the planning tool conditions in themselves did not have a positive effect on the quality of the resulting texts. However, the availability of a planning tool is no guarantee of adequate use. Further correlational analyses showed that *using* the Diagram to specify supports and refutations of positions and to state new arguments was positively related to the quality of the texts. Furthermore, a strong positive effect was found of the proper use of the Outline (especially in outline-text congruence) and its Advisor on textual structure and segment argumentation in the resulting argumentative text.

7.2. Task act differences between conditions and phases

The question addressed in this section is what writing strategies the participants discuss and how these relate to the quality of the final product. Task acts are the types of writing activities and strategies referred to by the participants in their chat in order to coordinate their actions in collaborative writing of the argumentative paper. Additionally, we were interested to see whether the presence of the different planning tools – the Diagram and the Outline – changed the distribution of strategies in the chat. Table 5 shows the means and standard deviations of the Task act percentages for the Control group and the Experimental group (i.e., all experimental conditions), as well as the mean differences on *t*-tests between these two groups. In addition, the numbers of dyads contributing to each type of Task act are given. As there were very few significant differences between the experimental conditions, these will not be discussed here.

Generally planning was done more often than executing in both groups (47% and 70% for planning vs. only 37% and 18% for executing), and Non-task related episodes occurred fewest (16% and 12%). In general, the distributions of episodes for the two groups over the three main Task act categories are very different: for the Control group it is 47:37:16, whereas for the Experimental groups it is 70:18:12. The Experimental conditions, then, tend to plan more than their Control group

Table 4
Descriptive statistics for text quality per condition

Condition	*n*	Textual structure		Segment argumentation		Overall argumentation		Audience focus	
		M	SD	*M*	SD	*M*	SD	*M*	SD
Control	39	6.76	1.13	6.19	1.36	5.75	2.37	6.20	2.10
Diagram	17	6.71	0.97	5.63	1.34	6.81	2.29	5.81	1.84
Diagram + Advisor	26	6.03	0.82	5.49	1.34	6.41	2.07	6.01	1.64
Diagram + Outline	23	6.44	0.83	5.64	1.32	6.16	2.25	6.20	1.60
Diagram + Outline + Advisor	11	7.15	0.88	5.42	0.84	5.76	1.69	5.57	1.00
Outline	18	6.59	1.00	5.90	1.06	5.74	1.80	6.04	1.95
Outline + Advisor	11	6.49	0.83	6.34	0.94	5.76	1.52	6.59	1.90
Total	145	6.56	1.00	5.83	1.28	6.06	2.13	6.08	1.81

Table 5
Descriptive statistics task act percentages in all phases for the control group and the experimental conditions and mean differences on independent samples *t*-tests

	Control group			Experimental group			*T*-test mean differences[a]
	n	*M*	SD	*n*	*M*	SD	
Planning level							
Plan-turn alternation	39	6.32	3.09	106	4.72	2.79	1.60**
Plan-coordination	39	9.51	3.72	106	13.52	4.56	−4.01**
Plan-Diagram				77	7.62	3.55	
Plan-external source	39	0.66	0.91	106	1.20	1.26	−0.54**
Plan-goals	39	1.85	1.15	106	1.59	1.21	
Plan-knowledge	39	2.45	1.45	106	8.11	4.44	−5.66**
Plan-layout	39	1.71	1.39	106	0.44	0.71	1.27**
Plan-notes	39	1.54	1.37	106	1.41	1.25	
Plan-Outline				63	4.04	2.31	
Plan-revision	39	3.44	1.86	106	3.67	2.24	
Plan-source	39	5.67	2.28	106	7.04	2.69	−1.38**
Plan-text	39	12.98	3.98	106	18.80	4.43	−5.82**
Total percentage Planning	39	47.31	5.75	106	69.70	6.11	−23.33**
Executing level							
Execute-word count	39	3.82	2.44	106	1.64	1.58	2.17**
Execute-Diagram				77	1.39	1.69	
Execute-external source	39	0.97	1.15	106	0.26	0.50	0.71**
Execute-goals	39	2.63	1.51	106	1.07	1.02	1.55**
Execute-knowledge	39	5.17	3.51	106	4.86	2.93	
Execute-notes	39	0.41	0.55	106	0.03	0.18	0.38**
Execute-Outline				63	0.49	0.96	
Execute-revision	39	9.74	5.49	106	1.56	1.56	8.17**
Execute-source	39	4.83	3.22	106	2.16	1.58	2.67**
Execute-text	39	9.49	3.52	106	4.98	3.17	4.51**
Total percentage Executing	39	37.05	8.24	106	18.18	5.14	18.86**
Non-task level							
Non-task program	39	3.11	1.75	106	3.82	2.38	−0.71*
Non-task social	39	12.54	6.15	106	8.28	5.08	4.25**
Total percentage Non-task	39	15.65	6.83	106	12.10	5.45	3.54**

n is the number of dyads.
[a] Only significant differences are shown.
* $p < 0.05$.
** $p < 0.01$.

colleagues. We would expect that this difference can be accounted for by the percentages for the categories related directly to the planning tools, such as Execute-Diagram and Plan-Outline. However, these Task act categories can only account for about 14% of the difference between Control group and Experimental conditions, whereas the significant mean difference for Total Planning is about 23%. From this we infer that the presence of the planning tools stimulates planning in general.

Within the planning categories, discussion about planning the text was done most frequent (13% and 19%), followed by planning coordination (10% and 14%). Both of these categories occur more frequently in the chat of the Experimental groups than in the chat of the Control groups. Within the executing activities Execute-text and Execute-knowledge are among the most frequent in both groups. However, for the Control group, Execute-revision is the most frequent Execute episode (10%) with 26% of the total percentage for Execute, whereas for the Experimental groups it only comes fifth with only 2% of the total number of Task acts, and only 9% of all Execute episodes. The Control group shows a significantly higher percentage of Non-task episodes than the Experimental conditions, especially of social talk (13% vs. 8%). However, the Experimental group talked significantly more frequently about the TC3 software. These results are hardly surprising, as the program was more complicated for the Experimental groups.

The total percentages of Planning, Executing, and Non-task episodes for the Control group and for the Experimental conditions over three phases of writing are presented in Fig. 4. The first chart of planning episodes in Fig. 4 shows that while the Control group plans relatively less frequently as the collaboration advances (from 51% to 42%), the Experimental groups plan slightly more frequently during the second and third phase compared to the first phase (from 67% to 70%). The total percentage of Execute episodes increases throughout the collaborative process for both groups, but with an increase from 23% to 41% the Control group shows a much larger increase than the Experimental groups from 15% to 20%. Finally, the Non-task episodes are most common during the first phase, with the percentage dropping significantly in the second phase.

Table 6 shows the correlations between the Task act percentages in all phases and the four text quality scores for the Control group and the Experimental groups. The total Planning percentage shows a negative tendency for the Control group, while the Experimental group gives a mixed picture: the chat on planning in the Experimental conditions correlates negatively with Segment argumentation, but positively with Overall argumentation. Within planning, the general tendency of the relation between the Control group discussion and text quality is negative, with a few interesting exceptions: planning goals, revision and text are slightly positively related to quality measures of the text. In the experimental groups planning turn taking and planning knowledge show some positive correlations, whereas planning layout, notes and text show some negative correlations with text quality scores.

The total Executing percentage shows a strong positive tendency for the Control group. When we look at the sub measures for the discussion of executing the task, this positive tendency is clearly present throughout, except for Execute-word count and Execute-notes. The latter also shows a clear negative tendency for the Experimental groups. Just as for Planning, both Execute-text and Execute-goals show positive tendencies for the Control group. Execute-revision gives a positive tendency for the Control group, but a negative tendency for the Experimental conditions. The executing chat about the planning tools both show negative tendencies for text quality, and – quite surprisingly – for Textual structure in particular. Both for the Control

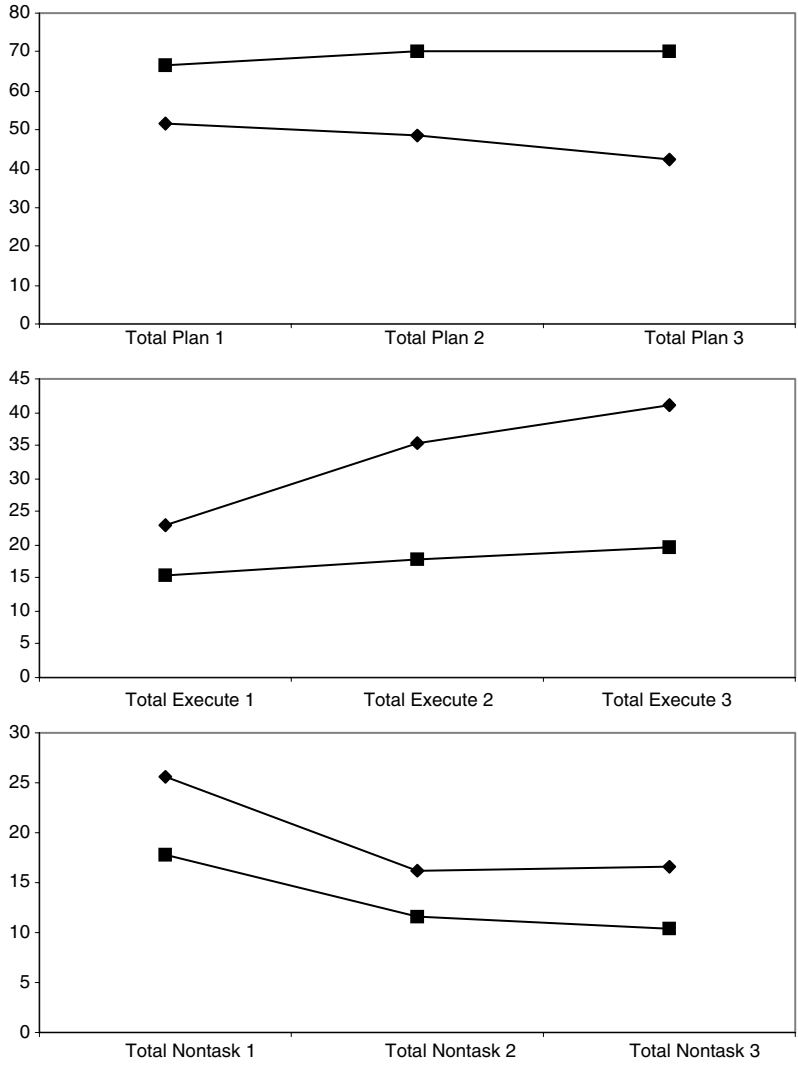

Fig. 4. Charts of planning, executing and non-task episodes in three phases of writing for the Control group and the experimental conditions.

group and the Experimental group there is a strong positive relation between Execute-knowledge and text quality.

As we predicted, the relation between Non-task chat and text quality is negative throughout the groups, sub measures of Non-task chat, and text quality measures, although the relation is most clear for the Control group.

Table 6
Correlations between task act percentages in all phases and text quality for the control group (C) and the experimental conditions (E)

	Textual structure		Segment argumentation		Overall argumentation		Audience focus	
	C	E	C	E	C	E	C	E
Planning level								
Plan-turn alternation	−0.13	0.22**	−0.12	−0.02	−0.03	0.18**	−0.04	0.17*
Plan-coordination	−0.12	−0.04	−0.21	0.02	−0.11	0.07	−0.19	−0.04
Plan-Diagram		−0.10		−0.02		0.10		0.07
Plan-external source	−0.19	−0.10	0.09	−0.07	−0.18	−0.01	0.10	0.10
Plan-goals	0.17	0.02	0.14	−0.08	0.08	−0.15*	0.15	0.00
Plan-knowledge	−0.07	0.15*	0.06	0.12	−0.01	0.21**	−0.10	0.04
Plan-layout	−0.02	0.15*	−0.01	−0.13	−0.08	−0.12	−0.09	−0.16*
Plan-notes	−0.05	−0.03	−0.22	−0.07	−0.05	−0.01	−0.04	−0.18*
Plan-Outline		−0.17		0.03		−0.08		−0.06
Plan-revision	−0.10	0.06	0.32**	−0.06	0.13	−0.09	0.21	−0.12
Plan-source	−0.27*	−0.12	−0.22*	−0.05	−0.19	0.04	−0.11	−0.08
Plan-text	−0.03	−0.05	0.25*	−0.06	−0.04	−0.18**	0.17	−0.06
Total percentage Plan	−0.33**	0.05	−0.02	−0.14*	−0.19	0.15*	−0.02	−0.09
Executing level								
Execute-word count	−0.04	−0.02	−0.16	0.19**	−0.04	−0.09	−0.15	0.10
Execute-Diagram		−0.23**		−0.01		−0.06		0.00
Execute-external source	0.06	0.03	0.02	0.08	−0.06	−0.02	0.08	0.04
Execute-goals	0.04	0.11	0.08	0.01	0.18	0.07	0.50**	−0.03
Execute-knowledge	0.29*	0.18**	0.15	0.12	0.23*	0.23**	0.45**	0.14*
Execute-notes	−0.25*	−0.18**	−0.24*	−0.08	−0.05	−0.09	−0.10	−0.11
Execute-Outline		−0.32**		0.00		−0.07		0.01
Execute-revision	0.22	0.05	0.18	−0.15*	0.14	−0.22**	0.12	−0.05
Execute-source	0.02	0.04	−0.08	0.14*	0.00	−0.06	−0.05	0.05
Execute-text	0.25*	−0.14	0.21	−0.05	0.20	−0.18**	0.34**	0.10
Total percentage Execute	0.37**	−0.03	0.20	0.08	0.28*	−0.10	0.45**	0.16*
Non-task level								
Non-task program	−0.08	0.02	−0.12	−0.07	−0.11	0.00	−0.27*	−0.19**
Non-task social	−0.20	−0.05	−0.25*	0.13	−0.20	−0.09	−0.53**	0.05
Total percentage Non-task	−0.20	−0.03	−0.26*	0.09	−0.21	−0.08	−0.54**	−0.04

* $p < 0.05$.
** $p < 0.01$.

Further analyses of the use of the tools within TC3 show that most students follow a logical pattern of activities: first they read the sources and the help on the task, the program, and the planning tools, and towards the end of the process they make less use of the private notes, and more of the planning tools – which are thus used for online planning rather than preplanning, as we would expect from these relative novice writers. In general, the results of the tool use analyses match the results for the Task act analyses, and we can conclude that the students do indeed develop different

types of knowledge construction and writing activities during the first phase versus the second and third phases.

7.3. Coordination processes: checking, focusing, and argumentation

The third question is how collaborating students manage to coordinate and adjust their actions to the processes of shared knowledge construction and problem solving that occur between them. As discussed before we will focus on Focusing (maintaining the same topic of discourse or task strategy), checking (guarding consistency in shared knowledge construction), and argumentation (negotiating and coming to agreement about inferences and conclusions). In these coordination processes, there is interaction between the students on task related strategies, cooperative intentions and communication processes. The relative frequencies of these specific coordination processes are derived by a number of indicative Dialogue acts (see Section 6). Table 7 shows the mean percentages and standard deviations for each of the three coordination processes for all conditions in the experiment.

Over 25% of the task related chat consists of checking activities, 18% is spent on focusing, and 10% on argumentation. This means that some 55% of the task related chat is devoted to coordinating the collaborative discussion. There were few significant differences between the conditions. The conditions with the Outline tool focus more frequently than the other groups. The difference is particularly clear when we look at the Diagram–Advisor condition, in which focusing ($M = 16.58$) happens significantly less frequently than the Diagram–Outline–Advisor ($M = 20.71$) and Outline ($M = 19.06$) conditions as was shown by a Bonferroni post hoc test at $p < 0.05$.

Table 8 shows the correlations of the coordination processes with text quality. Focusing correlates positively with Textual structure and Overall argumentation. Together with the positive tendencies of the other two text scores, this suggests that there is an overall positive relation between focusing and text quality. Checking, on the other hand, does not show any significant correlations with text quality. Argumentation correlates positively with overall argumentation in the text. As expected,

Table 7
Means and standard deviations of coordination processes in all conditions

Condition	*n*	Focusing		Checking		Argumentation	
		M	SD	*M*	SD	*M*	SD
Control	39	18.24	3.76	28.11	4.61	8.98	2.89
Diagram	17	17.45	3.06	26.22	4.35	10.74	2.98
Diagram + Advisor	26	16.58	2.63	26.60	4.78	10.51	2.77
Diagram + Outline	23	18.44	3.53	25.52	3.79	9.72	2.39
Diagram + Outline + Advisor	11	20.71	6.64	28.25	5.63	9.03	2.89
Outline	18	19.96	6.08	25.45	4.73	10.70	2.51
Outline + Advisor	11	19.04	3.19	24.15	3.33	9.04	2.71
Total	145	18.34	4.23	26.59	4.64	9.80	2.82

Table 8
Correlations between coordination processes and text quality

	Textual structure	Segment argumentation	Overall argumentation	Audience focus
Focusing	0.14*	0.09	0.12*	0.02
Checking	−0.01	0.02	0.04	0.03
Argumentation	−0.01	−0.01	0.13*	0.05

* $p < 0.05$.

there is a positive link between argumentation processes in the dialogue and the argumentative structure of the text. On the whole, the correlations found are weak.

To check whether particular conditions have an effect on the coordination processes, a multiple regression model of condition on coordination processes was tested. The directions of the effect of condition are shown in Table 9. Only the directions of significant regression weights are shown. The Diagram condition has a positive effect on argumentation in the chat, and so do the Outline and Diagram–Advisor conditions. The Outline condition also influences focusing positively, but it has a negative effect on checking. The Diagram–Outline and Outline–Advisor conditions also have a negative effect on checking. The Diagram–Advisor condition affects focusing negatively, whereas the Diagram–Outline–Advisor condition has a positive effect on focusing. The overall picture suggests that conditions with fewer tools have a positive effect on the use of argumentation, whereas the amount of checking is influenced negatively by the availability of the Outline tool.

To check the effect of coordination processes on text quality, we tested this model in a multiple regression analysis. Table 10 shows the directions of significant effects in this model. Focusing has a positive effect on Textual structure and Overall argumentation. Checking and argumentation also have positive effects on Overall argumentation. These results support our expectation that the specific processes of coordinating the communication of content facilitates the collaboration between students and thus influences the resulting argumentative text. Further analysis showed that these effects stayed when tool conditions were added in the regression model.

So on the whole, condition has an effect on Textual structure and Overall argumentation of the final text, both independent of and in combination with the coordination processes Focusing, Checking, and Argumentation. The Diagram–Outline–Advisor and the Diagram condition both have a positive effect on text

Table 9
Effects of conditions on coordination processes

	Focusing	Checking	Argumentation
Diagram			+
Diagram–Advisor	–		+
Diagram–Outline		–	
Diagram–Outline–Advisor	+		
Outline	+	–	+
Outline–Advisor		–	

Table 10
Effects of coordination processes on text quality

	Textual structure	Segment argumentation	Overall argumentation	Audience focus
Focusing	+		+	
Checking			+	
Argumentation			+	

quality through the coordination processes. Independently of the coordination processes, the Diagram–Advisor condition has a negative effect on text quality. The combination of the Advisor with one other planning tool negatively affects the text, but combining the Advisor with both planning tools has a positive effect on text quality.

8. Conclusions and discussion

The objective of the research project 'Computer Support for Collaborative and Argumentative Writing' (the COSAR project) was to study the relation between the collaborative processes and support of the planning process in argumentative writing. A groupware program was developed – called TC3: Text Composer, Computer supported and Collaborative – that allows collaborative writing by pairs of students, with or without support of specially designed planning tools for the generation, organization and linearization of ideas (the Diagram and the Outline). The three main research questions focused on the support of organization and linearization through the Diagram and Outline, constructive planning and coordination processes, and differences in constructive activities in different phases of the writing process.

We found that constructive activities indeed differ in different phases of the collaborative writing process, both in terms of the use of the software and in terms of the task discussion. Although planning activities occur throughout the process, discussing knowledge and actually writing the text seem to be the two most influential factors for text quality. Furthermore communicative coordination processes like focusing on topic of discourse, checking of new information and argumentation about relevant task related issues were indeed found to have a positive effect on the quality of the overall argumentation in the written essays. In general, the data confirm our idea that coordination is necessary on all aspects of the task, both in activities and in the dialogue, and that the collaboration needs to be adapted to the phase of the writing process. Our expectation that more mutual coordinating activities in the dialogue result in a more consistent shared knowledge structure, and in a better mutual problem solving and thus a better argumentative essay is supported in this respect. However these results could not fully be accounted for by the planning tools the students used. Comparing the Diagram with the Outline, the Outline tool was more successful. Availability and proper use of this planning tool have a positive effect on the dialogue structure, and on the coordination processes of

focusing and argumentation, as well as on text quality. Generally however, we found little or no evidence for a positive effect of the Diagram condition on coordination or on text quality.

Further analysis of the protocols showed that the Diagram often functions as a visual representation, and not as a basis for discussion or a tool for idea generation. It showed that specifically the participants in the Diagram–Advisor condition used the Diagram as a full report of their argumentation, which means they do not let the Diagram guide them in developing an argumentative structure. Thus, the Diagram only functioned as a visual representation, and not as a basis for discussion or a tool for idea generation. When a diagram reflects the discussion itself, it can be a valuable starting point for writing the text, and of benefit to textual structure. Students have little experience with the use of diagram tools. Perhaps a different approach to the task instruction, for example by giving the students an opportunity to experiment with the diagram tool and to experience the utility of the tool, might encourage the students to use the tool as it was intended, and thus lead to different results. The teacher should have a coaching role in this.

The results of our study show that proper us of the tools in a groupware learning environment like TC3 can help students in their coordinating processes while planning and executing a complex collaborative task. Working and learning actively, constructively and collaboratively in project based groups as asked for in the "study-house" curriculum, could be facilitated by network based collaborative "learn-and-work" environments in which students can work on projects, together or individually, in school or at home, at any time of the day, supported by dedicated (shared) tools and communication media. We have found teachers to be very interested in the possibilities in the groupware environments we are developing, not only for the students but also for the support they could offer for the teachers themselves. A problem in project based learning is that teachers often find it hard to coach and monitor project groups. They lack information about the learning and collaboration processes that go on in the groups. Electronic groupware environments can give online information to monitor these processes. In fact, continuing our research along these lines, we have designed and developed a new groupware work-and-learn environment to support both teachers and students doing collaborative science projects. In this *VCRI* environment (*Virtual Collaborative Research Institute*) students can work as project teams (two or more members) having their own workspace, self regulating the use of several (shared or private) tools and information sources, and having communication facilities within the project team, with other teams and with the teacher. The teacher can monitor online the communication and work that is being done in the different teams, reading intermediate products, commenting on them or on the collaboration that is going on. Our first results of the experiment we are doing, show that both students and teachers are enthusiastic about this way of doing and coaching collaborative learning projects and about the usefulness of the facilities the groupware environment offers. We hope shortly to present the analyses of the coordination processes this new environment supports for both students and teachers.

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