A Space for Debate

How diagrams support

collaborative argumentation-based learning

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How diagrams support collaborative argumentation-based learning

Ruimte voor Debat

Hoe diagrammen samenwerkend leren door argumenteren ondersteunen

(met een samenvatting in het Nederlands)

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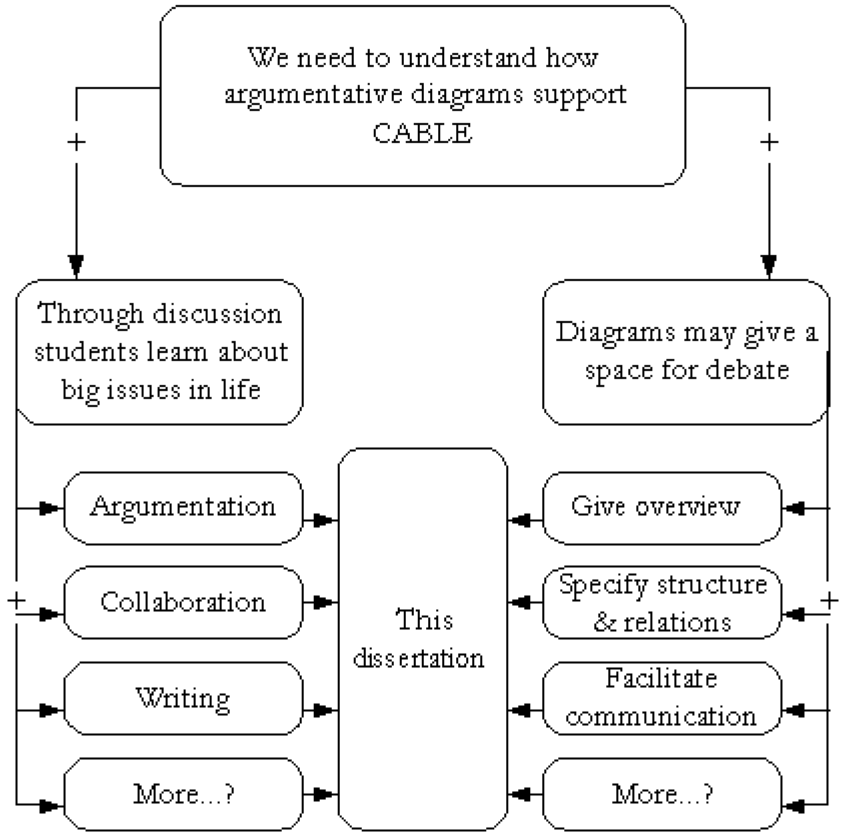
Introduction



Aim of the dissertation

This dissertation is about collaborative argumentation-based learning (CABLE) using computers. It is designed to understand the processes that are involved in CABLE, especially when these processes are supported with argumentative diagrams.

Scope

The big issues in society are mostly open-ended. There is not one easy solution. Instead there are different sides, each with their own view, their own arguments and consequences. These open-ended issues often come down to more fundamental issues, the ones that have been debated for centuries. Think about issues such as war and peace (should we interfere in Iraq?), life and death (should euthanasia be legalised?), culture and nature (should we build houses here or protect this area?). Of course, facts are important in these debates. In arguing we should declare war on Iraq because they have weapons of mass destruction, it should be made sure that this is indeed the case. Even more important is to understand what kinds of ideas and arguments play a role in the issue that is discussed. A good understanding of the issue with its different viewpoints and arguments helps us come to our own well-supported view, which in turn helps us make sense of our history and make desirable decisions for our future.

All views, arguments, decisions, facts, emotions, and consequences of an issue make up the *space of debate* of this issue. Most people only have knowledge of part of a space of debate, the part that they believe in, or the part they received from the media. The pedagogical aim in this dissertation is for people, especially secondary school students at pre-university level, to learn to broaden and deepen their spaces of debate. This way they will not only be able to discuss important issues, but also prepare for participation in the scientific community at university.

The space of debate does not have clear boundaries. Arguments and opinions can change, new arguments can arise, and old arguments may not be relevant anymore. Moreover, understanding the space of debate is not about having information of it, but about doing something with this information, such as weighing different sides, understanding the problems and reaching conclusions. Therefore, I argue that the best way to understand a space of debate is by debating.

Students are asked to discuss an issue in pairs. They can confront each other with their viewpoints, give arguments, and collaboratively construct their space of debate. In order to do this, students should be willing to really ‘dive into the topic’. They need to look at the topic from different sides (what are our points of view, do we know of other points of view), support and refute with arguments, evidence, examples (what arguments do we have for this viewpoint, can we refute these?), relate and weigh these to come to a conclusion (we think this viewpoint is more valid than the other one because…), and find more fundamental issues (e.g., in arguing about cloning, aren’t we in a sense talking about the meaning of life?)

The *space of debate* is a fuzzy thing, and students have problems exploring it. It is very difficult for people to discuss an issue due to problems with argumentation, epistemology, and collaboration. Argumentative diagrams might help students to get a clear overview of the space of debate. Not only can they see what they have been talking about, it can also help them to make relations between different parts of their discussion, or give them ideas on what to discuss next. Arguing about the space of debate is not a linear thing. A diagram may help students in structuring their discussion. A diagram made individually before discussion may help students in structuring their own knowledge, which makes it easier to enter the discussion with their partner. If their individual argument graph is available to their partner, it can also help them easily compare their views, and give a basis for the discussion. More functions are possible. However, these possible benefits of argumentation diagrams have not yet been validated. Does it indeed help students in their discussion? How do students use the diagram when they are working together? In this dissertation an answer to these questions is sought.

I have started from the assumptions that CABLE is an important way of learning in our modern society, that students are not so good at *cabling*, and that it needs support. The value of an argumentative diagram for collaborative argumentation-based learning is not clear yet. Moreover, we don’t know exactly how students really broaden and deepen the space of debate in practice. So far, researchers have mostly looked at effects of learning. For example they have checked whether students changed their opinion on a certain topic. The research on processes has mainly shown that it is very difficult for students to have a ‘good’ discussion on important issues, and led to a focus on basic conditions for a good discussion (e.g., motivation, task characteristics), and to ideas of supporting the process, without knowing about the learning mechanisms that come into play during collaborative argumentation-based learning. In short, a thorough analysis of both the problem and the proposed support are not available yet. Normally, you would say that you cannot start using an intervention (the argumentative diagram) without knowing what processes are involved in CABLE. However, the argumentative diagram changes the processes involved. That is why the combination of collaborative argumentation-based learning with a diagram is investigated in this dissertation.

General questions that arise in combining collaborative argumentation-based learning with argumentative diagrams are: Are theoretical affordances of using a diagram confirmed when doing research in schools? What are characteristics of diagrams to support collaborative argumentation-based learning? For what specific learning processes should a diagram be used? How do students work with the diagram? Do students understand the 'grammar' of the diagram? I want to investigate whether, and if so, how, when and why diagrams can support argumentation-based learning.

European background

This dissertation originated from a European project called SCALE[1], coordinated by Masoud Saeedi. SCALE stands for '*internet-based intelligent tool to Support Collaborative Argumentation-based LEarning in secondary schools'*. Eight partners[2] from six countries participated in the project. SCALE's primary goal was to develop a tool that could support CABLE in secondary schools, but an important secondary goal was to investigate how the tool could function in schools. After the SCALE project was finished, I was given the opportunity to write a dissertation on it. The focus of my dissertation is not so much on the development of tools, but on their possible functions for CABLE. I decided to give the argumentative diagram a central role in my studies.

Because of its European background, some parts of this dissertation are a collaborative activity between the partners of the project. For instance, the method to analyse students' interactions, called Rainbow, was developed during a scientific meeting with six partners. Two studies reported in this dissertation were carried out within the project. These are studies performed in The Netherlands, for which I

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[1] The SCALE project, March 2001 – February 2004, was funded by the European Community under the 'Information Societies Technology' (IST) Programme.

[2] London University (GB), Université Lumière Lyon 2 (F), Utrecht University (NL), University of Jyväskylä (FI), Universidade de Aveiro (PT), Armines- SIMMO (F), Számalk Systemhouse ltd. (HU), Ecole Nationale Supérieure des Mines – St Etienne (F).

was responsible. The other two studies are in line with the project, but were carried out after the project was finished.

Overview of chapters[3]

Six chapters follow this general introduction of the dissertation.

Chapter 2 provides the theoretical framework underlying the research and describes the most important concepts. The overall concept "Collaborative argumentation-based learning" is taken apart into the concepts of learning, collaboration and argumentation. Additionally, I consider the possibilities of supporting CABLE with computer representations, such as chat and diagram. The chapter ends with the general research questions.

Chapters 3 and 4 describe studies carried out within the SCALE project. Chapter 3 was done to find out what kind of interaction processes take place between secondary school students when engaging in CABLE, and to understand what kind of representations would be beneficial for CABLE. Chapter 4 describes a study done just after our computer tool, DREW, was developed. The study focused on the wider context in which tools are used.

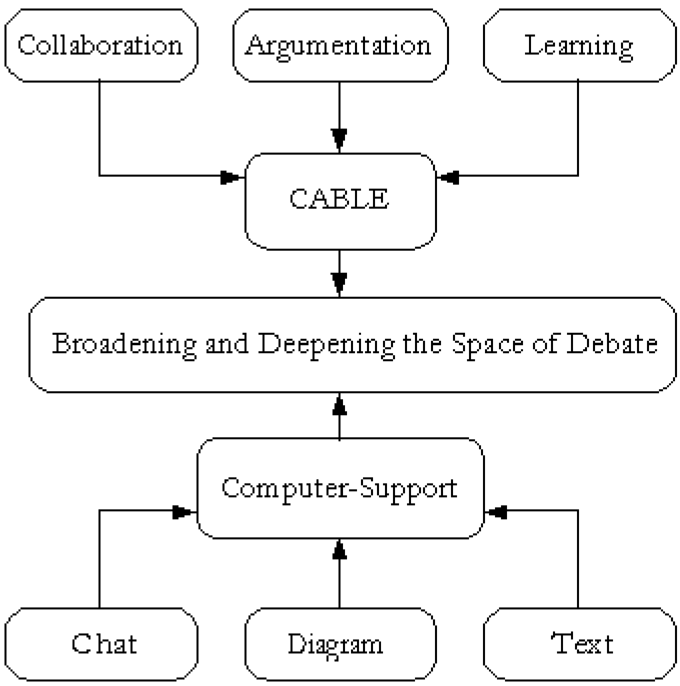
Chapters 5 and 6 describe studies carried out after the SCALE project was finished. The study from chapter 6 was carried out during my three-months-stay in Nottingham, the UK, funded by a Marie Curie scholarship. While chapters 3 and 4 are mainly focused on when to use diagrams for CABLE, chapters five and six are more focused on how to use these diagrams. In chapter five, argumentation is taken as the starting point to see what a diagram can do in terms of structuring and relating argumentative knowledge. In chapter six, I start from the other side, the diagram, to find out how the specifics of this representation could aid argumentative writing.

In Chapter 7, I present an overview of the main results and draw general conclusions.

[3] The studies reported in each chapter were conducted in collaboration with various colleagues. The text of the chapters is based on the manuscripts that were written about these studies.
Chapter 3 was based on: Van Amelsvoort, M., Andriessen, J., & Kanselaar, G. (2006). Representational tools in computer-supported collaborative argumentation-based learning: How dyads work with constructed and inspected argumentative diagrams. Manuscript submitted for publication. Chapter 4 was based on: Van Amelsvoort, M., Andriessen, J., & Kanselaar, G. (2006). Tools are not enough: learning activities in computer-based discussion. Manuscript submitted for publication. The other chapters were based on manuscripts in preparation.

2

Theoretical Framework



Computer-Supported Collaborative Argumentation-Based Learning

This dissertation is about computer-supported collaborative argumentation-based learning with diagrams. Computer-supported Collaborative Learning (CSCL; without the specification of argumentation) has been the focus of a tremendous amount of research in the last decades. In 1996, Koschmann suggested that CSCL could be called an emerging paradigm in educational technology. However, despite the amount and history of research into CSCL, there is not (yet) one theory for it. We also do not have agreed objects of study, no methodological consensus, no agreement about the concept of collaboration, or unit of analysis (Lipponen, 2002, p.78). On the positive side, this can be seen as reflecting the richness and diversity of the field. However, it does emphasize the need for precisely defining the framework in which this research is placed. Therefore, I discuss the important concepts of *computer-supported collaborative argumentation-based learning* one by one, going from general to more specific. I start with general learning theories, and then move to collaborative learning, and the specification of collaborative argumentation-based learning. The problems of collaborative argumentation-based learning are discussed, followed by the possible support a computer environment can offer. The second part of this theoretical framework is dedicated to computer-support, especially to the role of diagrammatic representations. The chapter ends with three general research questions.

Learning and Knowledge

Collaborative argumentation based learning (CABLE) is first of all placed in the general theory of constructivism (e.g., Bruner, 1990). People do not acquire, but actively construct knowledge. They selectively perceive and personally interpret information from the environment, using prior knowledge to relate new knowledge to. Knowledge cannot be passively 'copied' from teacher or textbook, but must be actively constructed by the learner (Von Glaserfeld, 1989). To a certain degree, it means that everyone perceives the world in his or her own unique way. Since everybody construes his or her own reality, this interpretation rejects objective reality.

Constructivism placed renewed focus on the context of learning and knowledge, starting among others with Vygotsky. Vygotsky (1978) argued that thinking and learning are derived from social interaction. As knowledge is situated in a cultural and historical context, meaning is the result of participation in social activities. Vygotsky speaks about development through social interaction, which is then internalised. Although the process of constructing knowledge is seen essentially as a social process, the focus is on the (internalisation of knowledge in the) individual. Later approaches to learning also shift their focus to a more 'social learning'; learning as participation in a social process of knowledge construction (Brown, Collins, Duguid, 1989). Other entities not only shape cognition, they are part of it (Petraglia, 1998). This pertains to the idea of cognition being shared or distributed (e.g., Pea, 1993; Perkins, 1990). Thus, although everybody construes his or her own knowledge, this knowledge is not unique, because it is arrived at by social and historical interaction (Bencze, 2005).

Many constructivists oppose preceding cognitivist and process-information theories that talk about knowledge that can be acquired 'in the head'. However, the constructivist theories do not imply that the preceding theories should be entirely abandoned. First, constructivist theory was introduced by Bruner (e.g., 1966; 1986) based on the study of cognition. Second, learning can still be defined as processing information. We are always exposed to an enormous amount of information, and we try to process that information in such a way that our environment makes sense (Anderson, 1990), whether this environment is an objective or created reality. Also, talking about learning as information processing does not exclude the idea of knowledge creation (as opposed to knowledge acquisition). How students process information and what they process is still their own creation, based on historical and cultural context, and on personal interpretation. Moreover, this information processing does not only have to apply to one person. It can also be a collaborative activity, with either a focus on the individuals within the collaborative group, or a focus on the group as information processing system (Salomon & Perkins, 1998).

Collaborative learning

Acknowledging that knowledge is situated in a social and historical context entails that all learning is in essence dialogical. Learning happens through dialogue with something or someone, or even yourself. The term 'collaborative learning' is often used in dialogic learning with (present) others. Dillenbourg (1999) describes collaborative learning as a situation in which two or more people work together on a joint goal. Roschelle & Teasley (1995) define the collaboration activity as "… a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem". Just being together is not enough for learning, learning occurs because the collaboration stimulates certain activities, such as verbalisation and negotiation, that in turn bring about learning processes.

The processes that are believed to be beneficial for collaborative learning again reflect the underlying theories of learning. Research in collaborative learning can be more or less socially embedded. The fact that collaborative learning always involves more than one person does not necessarily mean that research into collaborative learning has a social perspective. The collaborative situation can be seen as an environment in which the individual learns. Research with an individual perspective is focused at individual cognitive learning. The claim here is that interaction between students promotes individual knowledge construction because students have to verbalise their own knowledge and ideas. This verbalisation stimulates elaboration of knowledge, such as looking at a topic from different perspectives, relating concepts, and activating prior knowledge (Van Boxtel, 2000). Also, interaction can create a cognitive conflict, which forces the student to compare contradictory views (Doise & Mugny, 1994). In short, the social setting is seen as a learning system for the individual learner.

Research with a social perspective, on the other hand, regards knowledge construction to be a social process. Students come to a shared understanding by means of interaction and negotiation. Learning is not acquisition of knowledge and skills, but participation in a social process of knowledge construction (e.g., Wertsch, 1991). Taken even further, this knowledge-building process happens outside the learners (Bereiter, 2002). In these cases, individual cognition is not analysed, but the learners' interactions are object of study (Andriessen & Veerman, 1999; Baker, 1999b).

In my view, the distinction between individual and social learning is not clear-cut. I would argue it is even impossible to look at social learning while completely ignoring the individual. When analysing interactions between learners, we still look at the individuals interacting. Salomon and Perkins (1998) place individual learning and social learning at two ends of a continuum, but even on the ends there is still a combination of the two. Individual learning can be more or less socially embedded, and social learning can be more or less focused on individual processes. This dissertation follows Paavola, Lipponen & Hakkarainen (2002), who talk about analysing how individuals behave as participants in the innovative processes of collaborative knowledge creation, instead of dichotomising individual and social levels of learning.

Towards argumentation

The 'Argumentation-based' part in CABLE can be positioned as a special form of collaborative learning. Argumentation makes collaborative knowledge construction especially active. People cannot rely only on retrieving information from memory when arguing, because they have to react on what the other person says in order to defend or convince (Andriessen, Baker & Suthers, 2003). Voss and Means (1991) argue that argumentation is similar to reasoning, in the sense that people draw inferences from given knowledge to reach a conclusion that was not given. Therefore reasoning skills develop through argumentation. Learners have to negotiate about different meanings when arguing (Andriessen & Sandberg, 1999; Erkens, 1997). Reasoning about points of view and supporting arguments may lead to acceptance or rejection of information. Moreover, 'good' argumentation requires engagement in activities that enhance learning, such as looking at information from different sides, and looking for causes and relations to defend certain points of view. In our rapidly changing society, in which tons of information sources are available on the Internet and through other means, it is more and more important to be able to handle this information critically. Finding information is not the problem, thinking about information is.

However, argumentation is more than just a special form of collaborative learning. It *is* knowledge. In his book "Reality by Design" (1998), Petraglia argues that rhetoric could be the solution to the problem of 'objective truth' in constructivism. Knowledge is essentially rational, whether based on an objective truth or on a social argumentative process. Petraglia quotes Durham (1915), who observed that it is pointless to question humankind's basic rationality; we cannot help but think in terms of causes and effects. Maybe there is not one objective truth, but rational argumentation can be used to reason about our worlds, instead of seeking 'the right world'. Knowing then, in rational argumentation, is not about absolute truth or reality, but about what people accept to be true or real. This way, denying objective truth does not lead us to the relativistic and pessimistic stance that there can never be a shared world, and thus no shared knowledge. Although we do not progress towards the objective truth[4], we can progress towards better understanding, based on rationally satisfying argumentation (Petraglia, 1998, p. 162).

It is this process of meaning making, through argumentation, I am interested in. I want to know how students *do* learning, instead of researching learning outcomes isolated from situations of use (Koschmann, 2002).

[4] I personally start from the principle that there *is* a reality, although people may interpret this reality differently.

What is argumentation?

Argumentation deals with issues on which different opinions exist, and that are therefore subject to discussion (Wood, 1998). The fact that different people choose different sides in a discussion means that there are differences in the ideas and values they use to come to decisions (Stein & Miller, 1993). Argumentation consists at least of a point of view and a supporting argument for that view. It becomes dialogic if two or more people start discussing these views, for example, when someone does not agree with a viewpoint and gives an alternative viewpoint or a counterargument. Following the line of thought from the previous sections, people, in using argumentation, seek to establish what is probably true as well as what might be good or desirable for the future. They do this by weighing pros and cons or positive and negative evidence regarding alternatives (Kuhn, 1991).

The issues that are subject to argumentation are all more or less debatable. It is more difficult to discuss 'Paris is the capital of France' than to discuss 'the meaning of life'. The topic of discussion (e.g., discussion about factual statements, or about judgements or commonly held beliefs) largely determines what kinds of arguments are involved (Andriessen, Baker & Suthers, 2003), such as facts, ideas, beliefs, and emotions. Also, the goal of argumentation can be diverse, such as proving something to be true, making a point more logical, acceptable or plausible, defend from attack, and so on (Baker, 1999a).

Argumentation consists of a sequence of arguments, utterances that support (or reject) other utterances. Theories dealing with argumentation try to unravel the ideal or actual structure of argumentation. They are descriptive (looking at argumentation in practice) and/ or normative (looking at the quality or soundness of argumentation). Earlier theories were mostly focused on logical argumentation. Toulmin's model of argument (1958) was an important shift in attention towards everyday communication, describing necessary and possible parts of an argument. According to Toulmin, an argument contains at least a claim, data, and warrant, and possibly also a backing, rebuttal and qualifier. Toulmin's work was very influential, especially in research into written argumentation. However, Toulmin's model is not easy to use for collaborative discourse. The model regards only one side of an argument, and does not consider a proponent's and opponent's point of view (Van Eemeren & Grootendorst, 1999). Moreover, it cannot capture the development of an argument (Leitão, 2001).

It is very important to note here that I am interested in argumentation in order to learn. This has two consequences. First, I am not primarily aimed at improving argumentation in itself, but in how argumentation functions to promote

learning. I see argumentation as a special form of reasoning or thinking. Billig (1987) argues that much of the thinking we do is a silent argumentation with ourselves. In dialogic learning, argument is explicit in the interaction. Thus, in the definition of arguing to learn used here, the situation always requires at least two people communicating, either orally or by writing. Examples of theories on argument that are interactive in nature are Formal Dialectics (Barth & Krabbe, 1982), and Pragma-dialectics (Van Eemeren & Grootendorst, 1984, 1992). In the latter approach, for example, ten conditional rules are given for a critical discussion to take place. Second, argumentation for learning is not about formal, logic debate, but about negotiation. Other researcher may therefore not even use the word argumentation, but be more comfortable with negotiation. Students do not have to follow strict rules to try to win a debate, but negotiate the pros and cons of an issue together. These two issues will be further discussed in the next sections. In line with these issues, I follow Baker's (1999b) general definition of argumentation:
"*Argumentation is a form of interaction in which, minimally, speakers propose arguments in favour of views (propositions, statements, utterances, claims, conceptual viewpoints, … depending on the theoretical approach adopted), and counter-arguments in disfavour of them*."

Arguing to learn…

In the previous section, the question why argumentation would be beneficial for learning was briefly touched upon. I see argumentation as a form of thinking or reasoning. Learning takes place because this reasoning forces people to engage in activities such as explaining, explicitating, and relating concepts and arguments.

The fact that argumentation is generated by reasoning instead of retrieved from memory (Andriessen, Baker & Suthers, 2003) makes it especially suited for learning. Argument aimed at learning is not about logical or rhetorical argument. Rhetoric in Greek and Roman times was more of an art, and the art is not what makes learning possible. If the art of rhetoric was enough for learning, we could just give students the tips and tricks of argumentation. Most politicians are gifted rhetoricians, but they hardly seem to learn from their debates. They are often defending their own stance without listening to each other. By means of rhetorical tricks, the opponent is scored off. In arguing to learn, on the other hand, it is important to be open to each other's ideas, to try to understand the other, listen and react to one another. Moreover, an argument that is not logical, or 'false', may be very useful for learning, because it may trigger learners to redefine their concepts. Grice (1975) argues that an argument in a learning context should be evaluated on the basis of its collaborative value, or its contribution to the conversation. Argumentation for learning is about ‘confronting cognitions’; people express their knowledge and their ideas in such a way that differences between them are addressed and (possibly) resolved (Andriessen, Baker & Suthers, 2003). A well-known example of arguing to learn is the scientific community. Science advances as a result of argumentation in which people have the same interest in an issue and try to resolve it by means of discussion.

There is not much empirical research on how argumentation could contribute to learning. Since researchers have changed their focus from collaborative learning effects to learning processes (Van der Linden, Erkens, Schmidt & Renshaw, 2000), a few people have described the learning mechanisms in argumentation. For example, Andriessen and Veerman (1999, p. 165, in Dutch) say: “Reasoning about points of view and supporting argumentation can lead to acceptance or rejection of information. Also, good argumentation requires deepening activities that promote learning, such as looking at information from different sides, checking information on value and relevance, comparing information, and looking for causes and relations to defend or attack certain points of view.”

Baker (1996) described four possible mechanisms by which argumentation could lead to learning. First, the argumentative process could lead to changes in attitudes with respect to the topic debated. Beliefs can be adopted or dropped, but can also become more nuanced or precise. Second, the expression of arguments and counterarguments means students have to make their thoughts explicit, comparable to Chi’s et al. (1989) self-explanation effect, in which people learn because they explain a phenomenon to themselves. Third, new knowledge and understanding can be co-constructed in argumentation, when students defend or attack views or try to negotiate a compromise between their different views. Fourth, argumentation could lead to conceptual change because the necessity to define proposals, to differentiate concepts, and to move to discussing more fundamental issues are all intrinsic to argumentation itself.

It is arguable whether these four points should be called ‘mechanisms’. Baker (1996) does not make a clear distinction between argumentation as activity, the reasoning and learning processes that are behind it (learning processes), and the effects in terms of learning results. The learner’s activities bring about learning processes, which eventually lead to learning results (Boekaerts & Simons, 1995). Attitude change and conceptual change seem to be learning effects rather than learning mechanisms (although they do not have to be stable or persistent). They do not explain how these changes come about. Self-explanation and co-

construction could indeed be called learning mechanisms, although they are not exclusive *argumentation* mechanisms.

This dissertation aims at better understanding the mechanisms of argumentation for learning. A first attempt to distinguish the learning activities, processes and effects is therefore given in Figure 1.

Activities		**Processes**		**Results**
- exchanging arguments		- relating concept		- changing ideas
- defending		- redefining concepts		beliefs
- attacking	←→	- render more precise	←→	opinions
- explaining		- defining topics		attitudes
- justifying		- comparing information		- more knowledge
- …		- …		- …

Figure 1. *Argumentation-based learning: activities, processes, results*

In the schema, the focus is put on the individual learner. It is the individual that learns, but *in* a collaborative situation. The fact that the discussion takes place with two or more people continually changes the process. Because of the interaction, new knowledge and insights are achieved, but not only through the transmissional exchange of ideas. An individual's thinking can also be further developed because of questions asked by his/ her collaborating partner, or a new argument can gradually evolve during the discussion (Kuhn, Shaw & Felton, 1997). The group processes are no simple addition of individual processes. Schwarz, Neuman, Gil and Ilya (2000) found that generating, refuting or accepting arguments often is done by the group and not by the individuals. Schwartz (1995) found that collaborating students could create more than the sum of what they individually knew beforehand. For example, when two people perform a tango, their dance is more than the sum of their individual moves. In the following two sections, I will discuss the activities, processes and results that are important in this dissertation.

…argumentative knowledge

So far, I have been discussing how argumentation could lead to learning, but not what can be learned from argument. Oftentimes a dichotomy is made between learning to argue and arguing to learn. Learning to argue is about learning the 'language of argumentation', such as claims, arguments, and counterargument. It is about learning the argumentation *activities*, as depicted in Figure 1. Arguing to learn is related to what people remember about the topic after arguing about it, such as knowing more about cells after a discussion on genetically modified organisms (GMOs). Arguing to learn is mostly related to the *results* in Figure 1. Both learning to argue and arguing to learn are important in this dissertation. However, a third view is the focus of this research: arguing to learn argumentative knowledge. Argumentative knowledge is knowledge about a debate (Andriessen, Baker & Suthers, 2003). In discussing a topic, one gets to know the diversity of points of view and the kinds of arguments within a topic. For example, a learner is against GMOs because of the environment, and through the discussion she also learns about the relation between GMOs and health. Arguing to learn argumentative knowledge emphasises argumentative processes mentioned in Figure 1, such as relating concepts.

The idea of learning argumentative knowledge relates to findings of research that show beneficial effects of argumentation for learning. Kuhn, Shaw & Felton (1997) found that participants discussing the topic of capital punishment did not necessarily change their opinion, but their opinion got more elaborated, refined or nuanced. Both the quality and the reasoning of their arguments improved. Schwarz, Neuman, Gil and Ilya (2000) developed a task in which individual argumentation was alternated with argumentative interaction. They found that the individual arguments after discussion were less one-sided and more composed than before discussion. The reasons were more relevant and acceptable. In addition, more reasons were given for alternative viewpoints and the quality of the reasons was higher, less vague or personal, and more abstract. Reznitskaya, Anderson, McNurlen, Nguyen-Jahiel, Archodidou and Kim (2001) found that participation in argumentation promotes individual reasoning.

Arguing to learn argumentative knowledge leads to better understanding of the topic under discussion. In the goal to have students learn argumentative knowledge, I want them to collaboratively explore the topic under discussion. As I have argued before, the issues that are subject to discussion are often not readily solvable, but in using argumentation one can at least come to a temporary agreement or to temporary conclusions. Many issues have been debated for centuries, such as issues dealing with war and peace. Involved are different conceptions, facts, emotions, and different stakeholders with different points of view, all present in what we call the 'space of debate'. The goal for students is to collaboratively explore this space of debate, and answer questions such as: what kinds of 'facts' are there, what can we agree on, what different opinions are there, what arguments for and against?

Broadening and deepening the space of debate

Figure 2 shows the space of debate of a certain domain that students discuss together. The space of debate is created by a community of stakeholders involved in the domain. For example, in the domain of Genetically Modified Organisms (GMOs), stakeholders involved in the domain are governments, health organisations, environmentalists, and scientists. The domain does not have clear boundaries, for it can change, expand, or contract continuously. A and B are the ideas, opinions, and knowledge of two students about the domain under discussion. The part that is overlapping, part C, represents the ideas, opinions and knowledge they share. By means of arguing about the space of debate, the students are to reach a broader and deeper understanding of it (Baker, Quignard, Lund & Van Amelsvoort, 2002). Chinn and Anderson (1998) call this interactive argumentation, in which students collaboratively search an indefinable space. Students' shared space may expand, so that bigger parts of A and B also become shared, and C increases. Students could also expand their ideas, opinions and knowledge into domain D, so that they build their knowledge together. Scardamalia and Bereiter (1991; 1994) introduced the concept of knowledge building, to refer to creation of new cognitive artefacts that result from a collaborative discussion.

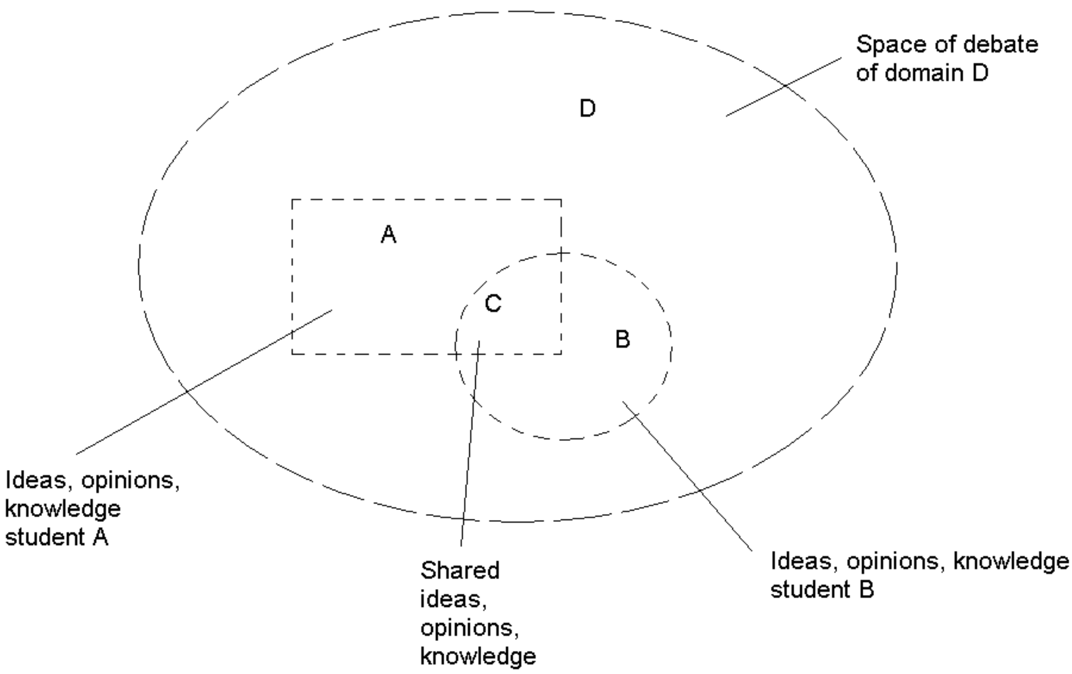


Figure 2. *Exploration of the space of debate*

Broadening the space of debate has to do with the different points of view that can be taken in the issue, the different subtopics that are distinguishable in the issue, and the arguments that accompany them. For example, broadening the space of debate in the domain of GMOs is understanding that GMOs have to do with health, environment, ethics, and so on, and that organisations such as Greenpeace have a different view on the topic than the factory that produces genetically modified food.

Deepening the space of debate has to do with being able to argue about argumentation, seeing the relations between the different views and subtopics, and understanding the more fundamental issues and questions involved. For example, in talking about whether GMOs should be allowed or not, students move beyond telling arguments that Greenpeace uses and give supports or counters on these arguments, or relate it to what a factory says in order to come to a weighed conclusion.

Relating broadening and deepening the space of debate to Figure 1, students explore the space of debate together by carrying out activities such as exchanging arguments, explaining, and justifying. These activities in turn bring about processes such as relating and (re)defining concepts. In the end, a broader and deeper understanding of the space of debate could lead to a change of ideas or beliefs, or a more nuanced view on the topic.

The difficulties of collaborative argumentation-based learning

In the previous sections, backgrounds of and reasons for the benefits of collaborative argumentation for learning have been discussed. Unfortunately, research has shown that it is very hard to get students to discuss. Although even three-year-old children are capable of using arguments, a well-substantiated argument is often still very difficult for adults (Stein & Miller, 1993). Kuhn (1991) had adults verbalise views on a number of societal subjects. Most people were able to give arguments for their own point of view, but were not so apt in giving arguments against it. Supporting arguments was even more difficult. People also have difficulties differentiating between theory and evidence, and generating genuine evidence. They often lean on their own beliefs, not on good theories. When their beliefs are undercut they prefer to ignore that (Wasson, 1960; Chan, 2001). They take into account what fits their own beliefs and reject the rest.

The above-mentioned research was done with individuals. When people have to use argumentation in interaction, some more problems arise, often social in nature. Thinking about another person's reasoning may be even harder than thinking about your own reasons for a viewpoint. Deep-level processing of the other's argument, expressing one's own argument and at the same time negotiating how to discuss may be too much of a cognitive burden to novice arguers (Kuhn & Udell, 2003). In addition, social factors begin to play a role in collaborative argumentation, such as fear of losing face, and trying to maintain friendships (Kreijns, 2004). People may experience conflict between displaying good argument skills and at the same time being morally and socially responsible (Andriessen, 2006).

Moreover, the research presented in this dissertation was carried out in secondary schools. The goal of the European project this dissertation derived from was to develop tools to support collaborative argumentation-based learning for secondary school students. Our research aims at secondary school students at pre-university level, because argumentation is an important and valued skill at university and in later life. However, research has shown that only 16% of first year university students could generate counterarguments and rebuttals (Cooper et al., 1984). Argumentation-based learning may thus also prove to be too difficult to use at a lower level of education or at an earlier age. For example, McCann (1989) found that high school students generated more counterarguments and rebuttals than sixth graders, but the overall rate for the high school students still remained low. When writing texts, adolescents slowly progress from justification to argumentation (Coirier, Andriessen & Chanquoy (1999).

In short, a lot of factors come into play that could hinder the discussion. It even led Bereiter (2002) to question the value of argumentation in learning. Although he believes argumentation is very important in knowledge improving communities, it is not enough. In Chapter 3, page 43 he states: *"Argumentation is a form of discourse often advocated in education. Raise an issue, get students to commit to a position on it, and then let those with opposing positions argue it out. Yet argumentation can proceed in quite a rational and civilized way without honouring any of these commitments. (Which, to my mind, raises serious questions about its value as an educational activity). Unlike social small talk, for instance, the discourse is supposed to get somewhere. Participants need to feel that something has been accomplished, that the state of knowledge in their community –however small or grand they may conceive their community to be- is in better shape than it was before."*

The fact that argumentation might also *not* lead to learning, does not mean that it cannot be a powerful tool for learning. However, Bereiter's point should be taken to heart by being very careful and precise in setting up conditions that promote argumentation-based learning. We need deliberately designed task sequences. At the least, the subject should be debatable, there should be a difference in opinion, and a desire to solve this difference with reason (e.g., Andriessen & Veerman, 1999; Goulder & Pouit, 1999; Quignard & Baker, 1999). In my studies, I have tried to comply with these conditions within the possibilities of school tasks and the school curriculum.

Besides meeting these minimal requirements of argumentation-based learning and carefully selecting the task, the students should also be supported during the *process* of discussion. It has been argued that students lack a well-developed schema to carry out argumentative discourse (e.g., Scardamalia & Bereiter, 1986). To summarize the problems mentioned in this section, students could use support in getting to know other viewpoints (without the possibility to ignore them), in generating evidence and counter-argumentation in the argument, in a socially 'safe' discussion, and in developing a schema for argumentation. One of the ways of supporting students during their collaborative argumentation is the provision of a computer environment. The next part of this chapter will therefore be dedicated to the 'computer-supported' part of computer-supported collaborative argumentation-based learning.

Computer support

Computer support for collaborative argumentation-based learning is focused on how the technology can enhance peer interaction, and how it can facilitate the sharing and distribution of knowledge (Lipponen, 2002). Many computer systems have been developed to support collaborative learning (see for example: *Belvédère*, Paolucci, Suthers & Weiner, 1995; *CSILE,* Bereiter & Scardamalia, 1994; *VCRI*, Jaspers & Broeken, 2005). Minimally, these systems provide an environment in which two or more people can communicate, either synchronously (chat) or asynchronously (e-mail; discussion board).

Computer-mediated communication has both advantages and disadvantages. For example, students miss the non-verbal communication that is present in face-to-face communication, such as gestures and facial expressions. These non-verbal cues aid to understanding in face-to-face communication. However, the lack of verbal cues may be an advantage for learning because learners have to communicate in a clear and explicit way, and check whether they understand each other (Erkens, 2004). In addition, social factors such as status that can hinder an oral discussion are less hindering in chat. Computer-mediated communication can combine the advantages of reading and writing. Through means of a conversation history students can read what they have discussed so far. Compared to face-to-face discussion, computer-mediated communication is slow.

This allows students to re-read and reflect on information (Veerman, 2000). Writing seems effective for learning (Rijlaarsdam & Couzijn, 2000; Bangert-Drowns et al., 2004). Writing down ideas, arguments and thoughts helps students structure their thinking process. The act of writing may also give rise to new ideas (Galbraith, 1992). When chat is used to communicate, some aspects of oral communication might come into play, because the utterances are mostly short, and turn taking is quick (Alamargot & Andriessen, 2002). The computer-mediated communication can further be structured by means of using sentence-openers or different roles for the students (Van der Puil, Andriessen & Kanselaar, 2004; Strijbos, Martens, Jochems & Broers, 2004).

The collaborative construction of knowledge cannot only be supported by supplying students with means to communicate, but also by providing (other) external representations, such as information sources, or argumentative diagrams. These external representations will be discussed below.

Representations

What are representations and how can they influence learning?

One of the benefits of using computers in collaborative learning is the fact that students can be supported in their learning process by providing them with extra aids, such as external representations[5]. Representations are objects or events that stand for something else (Peterson, 1996). For instance, a picture of two people is a representation of these people; chat is a representation of an interaction. Schnotz (2002) distinguishes descriptive representations (e.g., text) and depictive representations (e.g., diagram).

One can think of a representational tool as compensating for difficulties or as facilitating new processes (Hansen, Dirckinck-Holmfeld, Lewis & Rugelj, 1999). For example, a model of an electric circuit can make it easier for students to understand the flow of electricity, or a diagram of the argumentation process can

[5] In cognitive science, it is believed that there is a correspondence between external and internal representations. People have knowledge representations in their head, such as conceptual networks. Learning is the internalisation of the external representation. In my research, I don't want to speculate about the internal representations students have. We don't have the means to know exactly what is 'in the heads of the students'. The external representations are meant to help students in their argumentation process, not in exact internalisation of the argumentative diagram.

give rise to new discussion. In this dissertation, diagrams are used at the start of every chapter to function as an advanced organizer (Ausubel, 1963) for the reader.

Few theories specifically address the effects of representations on learning, and theories that address more than one representation or look at representations on different levels are especially scarce. An exception is the Symbol Systems Theory developed by Salomon (1979). According to this theory, each medium or representation can convey content via certain inherent symbol systems. Salomon argues that symbol systems highlight different aspects of content. They also vary with respect to ease of recoding, mental elaborations to be performed, and amount of processing they demand or allow. For example, watching television requires less mental processing than reading a book, and therefore mental schemas developed through the former are less elaborate than those developed through the latter. Salomon stresses that although different media can have different effects on learning, meaning extracted from a given medium depends upon the learner. For example, when someone is familiar with a topic, he or she may learn equally well from television or books, but when the topic is new, learning may be influenced by the way information is represented. Thus, symbol systems partly determine what and how much is learned, but instruction, the setting and the learner also influence learning with and from symbol systems. Salomon's theory was mainly based on research with media such as film and television. In later years (Salomon, Perkins & Globerson, 1991) the theory was broadened to include computers.

Towards diagrammatic representation

In spite of the lack of general theories about the influence of representations on learning, many researchers have carried out studies that contribute to our understanding of it. For example, Suthers (2003) compared several kinds of representations in interaction on scientific problems to see which representation elicits what kind of interaction. He looked at the use of diagrams, matrices, containers, text, and threaded discussions. He found that concept use is seen more in diagrams and matrices than in text, container and threaded discussion, while elaboration of relations is seen most in diagrams, then matrices, then containers. The search for missing relations is mostly seen in matrices, less in containers and diagrams, and least in text and threaded discussion. Schwarz, Neuman, Gil and Ilya (2000) compared triads of students who had to construct an argumentative diagram with students who had to make a for/against list. The students who constructed the diagrams constructed significantly better arguments than the other students, although this effect disappeared when students had to answer a questionnaire to evaluate individual knowledge afterwards.

As said before, the goal of the research presented in this dissertation is to have students broaden and deepen the space of debate by means of argumentation and negotiation. Students are expected to argue not only on their shared ideas and on their own ideas, but also on the things in the domain they have not individually thought about (knowledge building; Scardamalia & Bereiter, 1994). When looking at Suthers' findings, either a matrix or a diagram should be used to get students to think about the issues they have missed so far. However, a matrix on the whole domain might not only be out of reach, but also pedagogically less justified, pushing students in certain directions. Therefore, a diagram will be used to support students in investigating the breadth and depth of the space of debate, as well as the relations between the concepts they use. After all, both concept use and elaboration of relations have especially been found when students use diagrams in carrying out their task. A diagram can be used to manipulate structure and content of argumentation, but also to structure the way students argue.

The diagram in this dissertation is an argumentative diagram, consisting of boxes with claims and arguments, and arrows indicating positive or negative relations between boxes. It doesn't matter where in the diagram certain boxes are placed when viewing them separately (a certain topic does not have to be in a certain place), but the interdependence can be shown by a certain arrangement of the boxes (see Figure 3).

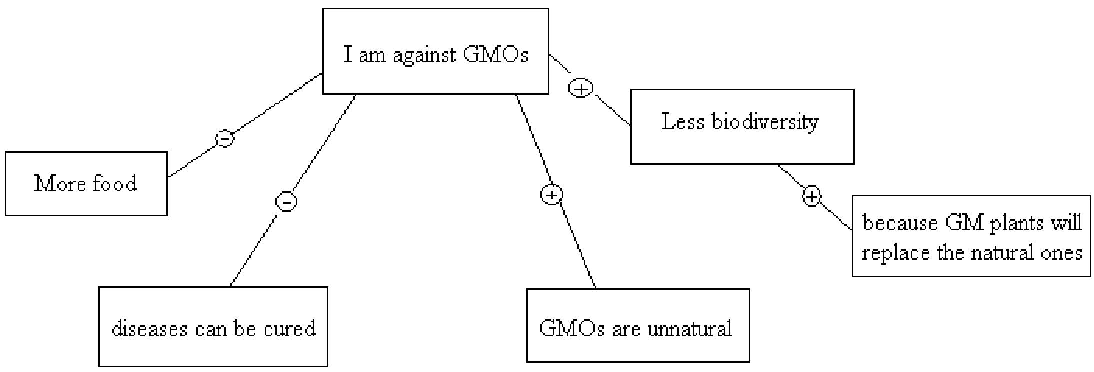


Figure 3. *Example of argumentative diagram*

Lohse, Biolsi, Walker and Rueter (1994) contributed to the field by making a classification of visual representations. They had subjects name, rate, sort and explain 60 graphical items. Eleven categories of visual representations emerged, such as graphs, tables, time charts, and networks. The argumentative diagrams just described can be placed in the category named “network charts”. Network charts show the relationship among components, Relationships are indicated by lines, arrows, proximity, similarity, or containment. Meaning results from an efficient spatial arrangement of the data. The subjects in the study by Lohse et al. (1994) rated the network charts as non-numerical, containing a lot of information, non-spatial, and unattractive. Contrary to these network charts that were presented to individual subjects, argumentative diagrams are mostly constructed collaboratively. This may have consequences for the ideas students have about these diagrams; they may not think they are unattractive, or may put less information in the argumentative diagram.

Possible benefits of diagrammatic representations

In the literature, many reasons are given why representations would be beneficial for learning. The beneficial effects of representations can be summarised in four main reasons (given below). It is important to note that these benefits are based on a range of literature into graphical representations; from graphs as models to argumentative diagrams; from individual to collaborative learning; and from theoretical ideas to empirical research.

1. Diagrams are concrete. Diagrams express abstractions in a concrete way (Suthers, 1999). They require less interpretation than a verbal representation (Larkin & Simon, 1987). For example, a diagram representing a fork to the right of the plate disambiguates the text ‘a fork is next to a plate’. Cox (1999) argues that as graphical representations constrain interpretation by limiting abstraction, they provide learners with more salient and vivid feedback to compare against their explanations.

2. Diagrams show structure and relations. Graphical representations make the structure of the argumentation visible (Schwarz, Neuman, Gil & Ilya, 2000). A graph helps learners see patterns and discover new relationships (Suthers, 1999). It fosters discussion about relations, because they are clearly visible in the diagram (Suthers, 2001). The syntactic structure of arguments in a diagram can help students to formulate their statements (Chryssafidou, 2000).

3. Diagrams give an instant overview. A visual representation gives an instant overview. An argumentative diagram gives a complete record of the argumentation process

(Carr, 2003). It makes the differences between students' opinions easily visible to them (Baker, 2003a).

4. Diagrams can stimulate and guide communication and reasoning. Representations stimulate and guide the communication and reasoning process (Suthers, 2001). They can be used as a shared reference to construct and evaluate arguments together, which may lead to more task-relevant utterances and the use of abstract concepts (Schwarz, Neuman, Gil & Ilya, 2000). They form the basis for discussion, and can also be a tool for idea generation (Kanselaar, Erkens, Andriessen, Prangsma, Veerman & Jaspers, 2003). Constructing representations forces students to make their opinions and arguments explicit, which can stimulate them to negotiate and elaborate to come to a shared understanding of the space of debate (Van Bruggen, Boshuizen & Kirschner, 2002; Suthers, 2003).

Limitations of diagrammatic representations for learning

In the section described above many claims are made about representations, but they cannot be taken for granted. First, not all claims are supported with empirical evidence. The work that does investigate effects of representations does not give a clear idea of the underlying processes. Scaife and Rogers (1996) argue that there is "a fragmented and poorly understood account of how graphical representations work, exposing a number of assumptions and fallacies" (p. 185). They point out that we do not have a clear idea of the cognitive processes underlying the effects we find. Second, results of representations for learning have been mixed. As mentioned before, the availability of representations do not miraculously produce learning. As with new inventions and techniques, research undertaken to demonstrate an advantage of computer systems with graphs or models soon showed that learning did not always occur (see Kozma, 1994, for a discussion of the influence of media on learning). This led to new research in which an effort was made to more precisely understand processes and conditions under which representations could be useful for learning. For example, certain representations are only useful for certain kinds of learning. Schnotz and Bannert (2003) refer to this as computational efficiency. Also, the effect of representations depends on the kind of task and the knowledge of the learner (Goldman, 2003). For example, Lowe (1993) found that experts copy and recall relevant information in a weather map differently than novices. Third, there are so many different kinds of studies, different kinds of representations and tasks, that it is very hard to generalize results (which probably explains the lack of general theories). We cannot automatically assume that all benefits mentioned above also apply to argumentative diagrams. Three aspects in research have to be considered to decide what kinds of benefits could occur in argumentative diagrams. First, we need to distinguish between natural science tasks and open tasks. Second, a distinction between constructed and presented representations is important. Third, we need to consider individual and collaborative use of representations. I will briefly touch upon these issues.

An argumentative diagram in the studies presented in this dissertation is used in open tasks. Most of the research on diagrams has been in natural science tasks. A diagrams is then often a model students have to consult on lighting, electricity, pumps, chemical reactions and so on (e.g., Mayer, 2001a; 2003). Text is completed with diagrams, which is found to enhance comprehension and learning. However a model in a science task is completely different from a diagram in an open task. It is a simplification of reality students have to understand and remember. It can be (partly) true or false, but should not be interpreted in different ways. Moreover, the symbols used in natural science representations are built on intuitive or acquired consensual representations, which is much less apparent in representations on open tasks (cf. De Westelinck, Valcke, De Craene & Kirschner, 2005). An argumentative diagram on an open task does not have one correct appearance students have to arrive at, and can be created and interpreted in many different ways.

An argumentative diagram is constructed by students instead of presented to students. In literature, there is often no clear distinction made between the two. Reasoning with presented representations is focused on how learners interpret and interact with these representations (e.g., Zhang, 1997; Mayer, 1976). In research on constructing representations (e.g., Cox & Brna, 1995; Schwartz, 1995), the focus is on how students achieve this, and what is learned from it. It is not yet clear how the two situations differ in terms of cognitive processes (Cox, 1999). One can imagine however, that different processes play a role in learning with constructed or presented diagrams. For example, Suthers (2003) found that a lot of argumentation arises *from* constructing a diagram (rather than *in* the diagram). A static diagram that is inspected instead of constructed may not help fostering discussion.

An argumentative diagram can be constructed individually, but is mostly constructed in negotiation with others. When a representation is used by one person, it may act as an external memory, and may work well, even if someone else could not interpret it (Van Bruggen & Kirschner, 2003). However, when these representations have to be shared, more time is needed to make the representation readable and understandable for both partners (Cox, 1999). People working together may have different representations of the task at hand, which they first have to converge or make clear. On the other hand, Fay, Garrod, Lee & Oberlander (2003) found that shared representations gradually become more and more abstract, to the extent that people outside of the interaction find it hard to understand the representations. Although these abstract forms might be difficult for outsiders, the collaborators reduce their collaborative effort (Clark & Shaefer, 1987).

Argumentative diagrams for Collaborative Argumentation-Based LEarning

From the previous sections it may be inferred that we have many ideas of how graphical representations can be beneficial for learning, but that we have to investigate whether and how these beneficial effects apply to argumentative diagrams in collaborative argumentation based learning. Therefore, the beneficial claims need to be specified to claims for argumentative diagrams in CABLE.

1. Diagrams are concrete. If this claim is correct, argumentative diagrams could disambiguate relations between arguments. Relations in an argumentative diagram are either positive or negative, and always have to go from one argument to another. In text, relations do not have to be polarized, and indeed, are not necessarily indicated at all. However, the concreteness of diagrams may also be a drawback in argumentation. They may miss the nuances that are easier in a textual representation, such as ‘maybe’, and ‘sometimes’.

2. Diagrams show structure and relations. With an argumentative diagram, students could structure the argumentation, which may make it easier to broaden and deepen the space of debate. For example, they could structure the diagram in such a way that breadth is depicted horizontally and depth is depicted vertically. The fact that students have to relate boxes with arrows may also help them to relate and weigh different concepts and arguments more.

3. Diagrams give an instant overview. This perceptual feature of the diagram can make it easier for students to see what they have and haven’t addressed, showing positive and negative relations at a glance. They can also compare their ideas more easily (seeing the parts A, B and C of Figure 2). However, argumentative diagrams may not easily give an instant overview. One of the characteristics of argumentative diagrams that distinguish them from many other kinds of graphical representations is that an argumentative diagram is very textual. Boxes in an argumentative diagram are filled with text. If the diagram is big, filled with text and complex relations, it may not give an instant overview anymore.

4. Diagrams can stimulate and guide communication and reasoning. Seeing the argumentative diagram students build together may ensure more co-construction because the students can build on each other's arguments in a shared view.

Even if these claims are correct, we still do not know exactly how and when to use argumentative diagrams for CABLE. For example, we do not know whether the diagram is best constructed before or during discussion. This can be explained by going back to Figure 2. Constructing diagrams to prepare for discussion can activate learners' prior knowledge, or structure and relate information they receive about the topic. It can explicate subspaces A and B in Figure 2. The advantage of individually constructed representations is also based on the hypothesis that people will argue more when they clearly see the things in which they differ (Baker, De Vries & Lund, 1999). During the discussion, diagrams then form the basis for discussion (Kanselaar et al., 2003). As Cox (1999) puts it: "The benefits of constructing an external representation are reaped when information is read-off from it" (p.354). Therefore, constructing a diagram before discussion may be mostly related to the third benefit of giving overview. Constructing a diagram together during discussion, on the other hand, is more related to the fourth benefit of guiding communication and reasoning. When students construct a diagram during discussion, the diagram becomes a medium through which students discuss and build on each other's ideas (Suthers, Girardeau & Hundhausen, 2003; Van Drie, Van Boxtel, Jaspers & Kanselaar, 2005). They can talk about their own ideas ($A \cap B$) and see where they agree (C) and disagree ($A \cap B \neg C$), or rather where they have the same and different argumentative knowledge. They can specifically relate their arguments in the diagram so that they change or increase C into D.

We also do not know exactly what learning processes are supported by the diagram, or how students use the diagram while learning. For example, do students indeed use a diagram during discussion to explore the space of debate together, or do they put arguments in without considering their how they are related? These diagrammatic issues will be the focus of my research into CABLE.

Summary and research questions

The general aim of this dissertation is to understand how an argumentative diagram in a synchronous computer-environment affects collaborative argumentation-based learning (CABLE) for students of pre-university education. Collaborative argumentation-based learning is defined as learning from discussing an open-ended topic together. From a (socio-) constructivist perspective, students learn from actively constructing their knowledge together. The focus of this dissertation is on how students actively broaden and deepen the space of debate collaboratively. Broadening the space of debate can be described as acknowledging that different points of view can be taken in the issue, or discussing the different subtopics that are distinguishable in the issue, and the arguments that accompany them. Deepening the space of debate can be described as being able to argue about argumentation, seeing the relations between the different views and subtopics, and understanding the more fundamental issues and questions involved.

Collaborative argumentation-based learning is not easy. Both cognitive and communicative aspects determine to what extent students are able to broaden and deepen their space of debate. To support students in their collaborative exploration of the space of debate, we propose to use a computer program, in which chat and argumentative diagrams are used. We propose that chat can help students in their discussion, because chat has some advantages over face-to-face discussion and over computer-mediated asynchronous discussion. We propose that an argumentative diagram can help both cognitive and communicative aspects in students' attempt to broaden and deepen their space of debate. Broadening and deepening the space of debate is supported because the diagrams can show structure and relations of the argument, because they can helps students to get an overview of the discussion and keep focussed on the discussion.

However, not much is known about exactly how and when to use an argumentative diagram to support collaborative argumentation-based learning. We do not know whether the diagram is best constructed before or during discussion. We do not know what learning processes are supported by the diagram. We do not know how students use the diagram while learning. The research questions in this dissertation can be divided into three broad categories. In the first category, different settings are compared: Argumentative diagrams in collaborative learning tasks are compared to argumentative texts; the construction of argumentative diagrams is compared to the inspection of argumentative diagrams; and students' labelling of boxes is compared to labelling of arrows in a diagram. In the second category, students' actions in CABLE are investigated in detail: I inspect how they interact with each other and with the tools; and how individual differences influence CABLE. In the third category, the argumentative diagram itself is investigated: I research the specific features of argumentative diagrams, their saliencies and constraints, and relate these to CABLE. This combination of research questions should lead to the general aim of *understanding the relation between collaborative argumentation-based learning and the use of argumentative diagrams*.

Research questions

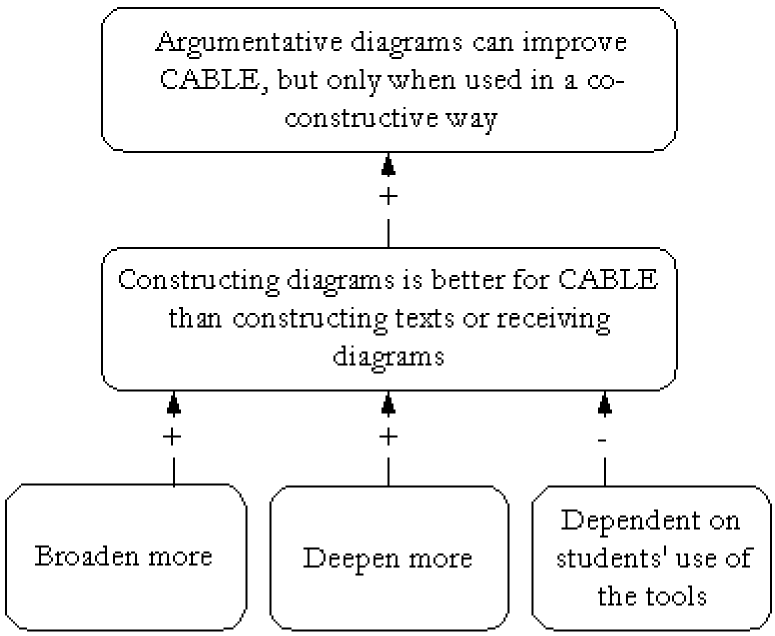
How does the construction of argumentative diagrams in a synchronous computer environment by students in pre-university education affect their collaborative argumentation-based learning (CABLE)?

a. How do different (forms of) representations affect collaborative argumentation-based learning?
b. What is the nature of students' activities in collaborative argumentation-based learning with diagrams?
c. What are the specific features of diagrams that can be fruitful for collaborative argumentation-based learning?

3

Representational tools in computer-supported collaborative argumentation-based learning:

How dyads work with constructed and inspected argumentative diagrams



Introduction

We probably all use argumentation in our daily lives. Whenever people have different opinions on an issue, they use argumentation to convince, to clear the air, or maybe just to have fun. This article focuses on collaborative argumentation with the goal of learning. Collaborative argumentation-based learning (CABLE) is increasingly used in education, because current practice - at least in the Netherlands - values peer collaboration and construction of knowledge. Through argumentative interaction, students exchange views and arguments, collaboratively constructing their knowledge of the "space of debate".

Using argumentation for collaborative learning can be difficult (e.g., Baker, 1996; 1999). Some researchers have suggested that representational tools can be used to facilitate argumentative learning (e.g., Suthers & Hundhausen, 2003). A tool that is often used is an argumentative diagram. Argumentative diagrams visualise the domain that is discussed. However, we do not know exactly how such diagrams contribute to learning or how learners should use them. For example, is it enough for learners to merely inspect argumentative diagrams, or should they actively construct such diagrams to facilitate learning? The present study aims to contribute to our understanding of the way in which representational tools can be used for learning by investigating argumentative diagrams in collaborative learning in secondary schools.

Collaborative Argumentation-Based Learning

People learn from argumentative interaction because it involves reasoning instead of merely retrieving information from memory (Andriessen, Baker & Suthers, 2003). In argumentation they have to make their thoughts explicit, which can aid learning through the self-explanation effect (Chi & Van Lehn, 1991). They also need to look at information from different sides, searching for causes and relations in the topic under discussion (Veerman & Treasure-Jones, 1999). Argumentative discussion may thus lead to a broader and deeper understanding of the "space of debate", which represents all possible positions and arguments regarding a certain topic. The space of debate can be finite, for example when students have to solve a problem in physics. In such cases, there are relatively stable ideas about what is correct and what not, which limits the exploration of the space of debate. In our view, there is more to be gained from argumentation when students work on open problems.

In argumentative problems without unique solutions, such as the desirability of genetically modified organisms, the space of debate is constructed by discussing different positions, ideas, and values. This space of debate is infinite. Learning is then defined as collaboratively broadening (i.e., using multiple viewpoints and subtopics) and deepening (i.e., using more elaborate arguments) the space of debate by constituting and transforming concepts and arguments. A broader and deeper understanding of the space of debate may lead to conceptual changes or attitude changes regarding the topic (Coirier, Andriessen & Chanquoy, 1999; Baker, 1996, 1999).

Several studies have found positive learning effects of collaborative argumentation. For example, Kuhn, Shaw and Felton (1997) found that dyadic discussion by adolescents on the topic of capital punishment improved reasoning about that topic. Erkens (1997) found that collaborative argument significantly improved 10-12 year old children's ability to solve problems. Finally, Reznitskaya et al. (2001) found that discussion by high school students promoted individual reasoning in writing persuasive essays. Students in the discussion-condition wrote essays that contained more arguments, counters, rebuttals, more formal argumentation, and more references to text information than students in the control condition who did not engage in collaborative discussion. These studies suggest that argumentation promotes learning, but such effects do not arise spontaneously.

Although argumentation is fairly often used in daily life, many people have difficulties constructing 'good' arguments. For example, Stein and Miller (1993) found that three-year old children are already capable of using arguments, but producing a well-substantiated argument is still very difficult for adults. Kuhn (1991) did an extensive study in which she asked adults to individually present and explain causal theories for societal issues. She found that people were apt at giving and explaining their opinions, but that only a third of them could come up with alternative views or counterarguments for their own view. Weighing different theories was seen even less often. When people discuss a topic together, they exchange views and arguments that can be used to construct knowledge. Unfortunately, people tend to ignore information or ideas that do not fit their own ideas (Wason, 1960; Chan, 2001). Additionally, social factors come into play in discussion. People may be afraid to lose face or to get into a fight. For effective argumentation, people have to be willing to argue, and need to have some common ground to make discussion possible. Taken together, these findings constrain the effectiveness of argumentation for learning.

Representational Tools

Representational tools have been suggested to support CABLE and alleviate many of the problems with argumentation. Representations can guide, constrain, or even determine cognitive behaviour (Zhang & Norman, 1994). Suthers and Hundhausen (2003) showed different effects on learners' discourse in the area of science. For example, matrix and diagram prompted students to discuss evidential relations more than a plain text.

Diagrams have been argued to have specific advantages as representational tools for argumentation-based learning (see Figure 1 in the method section for an example of an argumentative diagram). Argumentation can be visualised in diagrams by putting arguments in boxes and relations between them in arrows. Diagrams may benefit both construction and communication of arguments for many reasons, such as clarifying relations (Suthers, 2003), illustrating the structure of argumentation (Schwarz, Neuman, Gil & Ilya, 2000), giving overview (Larkin & Simon, 1987), helping to maintain focus (Veerman, 2000), and promoting reflection of alternative perspectives, solutions, and critiques (Kolodner & Guzdial, 1996). Thus, diagrams could be an important tool in supporting CABLE. However, until now there have been only a few studies showing that diagrams actually do support collaborative learning in the classroom (e.g., Toth, Suthers & Lesgold, 2003; Van Drie, Van Boxtel, Jaspers & Kanselaar, 2005).

In our view, there are at least three important questions to be answered about the conditions under which diagrams can be supportive for CABLE. The first question is: what are the specific advantages of diagrams over other representational tools? The most frequently used alternative for diagrams is a textual representation of arguments. A salient difference between text and diagram is linearity. A text is a linear representation, meaning that arguments are presented in a sequential fashion. In contrast, a diagram is non-linear because it displays arguments and argumentative relations in a two-dimensional space. It is exactly this two-dimensional space that has been argued to have specific advantages, because argumentation is in essence not linear (McCutchen, 1987; Coirier, Andriessen & Chanquoy, 1999). In addition, a diagram allows for multiple relations between arguments, by linking boxes with more than one arrow. Although text has many devices for expressing complex relations, such as advance organizers, and argumentative connectives that usually indicate a single relation between the previous and the following phrase (e.g., 'but' or 'because'), relations in a diagram are more salient (Suthers & Hundhausen, 2003). The text has to be processed sequentially when building a model of non-linear relations, while in a diagram this can be seen through parallel visual processes. Another advantage of diagrams over texts is that the limited space of boxes constrains the detail of the argument, allowing a clear overview; more topics can be represented with less detail. In spite of the theoretical advantages of diagrams for CABLE, texts may be easier to construct for people who are used to a narrative way of thinking (Chinn & Anderson, 1998). Although argumentation in itself is not linear, argumentative interaction happens through a linear dialogue. It may be difficult for students to represent their linear dialogue into a two-dimensional diagram. Thus, the first focus of the studies in this manuscript is on how the proposed differences between argumentative texts and diagrams contribute to broadening and deepening the space of debate in CABLE.

The second question regarding the use of diagrams in CABLE is about the situations in which a diagram would be conducive to learning processes (i.e., what processes and activities do diagrams foster, and when?). A clear distinction should be made between construction and inspection of diagrams (Cox, 1999). For example, the alleged benefits of showing the structure of argumentation may only arise if students actively construct diagrams themselves. On the other hand, giving an overview or helping to maintain focus may be promoted most when students inspect a diagram. The question of how to use a diagram is closely related to the question of when to use a diagram. For example, when students construct a diagram *during* discussion, it becomes a medium through which they discuss and build on each other's ideas (Suthers, Girardeau & Hundhausen, 2003; Van Drie, Van Boxtel, Jaspers & Kanselaar, 2005). Constructing a diagram *before* discussion activates prior knowledge, and helps students to structure and relate information about the topic. The advantage of individually constructed representations before discussion is also based on the hypothesis that people will argue more when they clearly see the things in which they differ (De Vries, Lund & Baker, 2002). *During* the discussion, diagrams form the basis for discussion if they present a clear and concise overview of the space of debate, or an individual point of view (Kanselaar et al., 2003). The differences between constructing and inspecting a diagram during CABLE have become more important in recent years, because new technologies make it possible to automatically present students with an argumentative diagram of the discussion they are engaged in. The linear, argumentative discussion is automatically put into a two-dimensional structure. This was also a goal for the SCALE process this study was part of. Thus, the second focus of our studies is the question whether it would help if someone else (e.g., an automatic system) represents argumentative texts as argumentative diagrams for later use during a discussion between students, compared to diagram construction by the learner. Because there was no automatic system available yet, the researchers changed texts into diagrams by hand (for more information, see method section).

The third question is how learners are actually using diagrams. While research has shown that different representations (e.g., diagrams and texts) provoke different learning activities (Zhang, 1997; Suthers & Hundhausen, 2003), representations do not determine learning activities. Perceived task goals, personal goals, and abilities may influence the realized benefits of argumentative diagrams as learning tools. For example, Postigo and Pozo (2000) described how a presented visual (mathematical) graph was only helpful for learning when interpreted globally. Local inspection led only to a focus on explicit elements, whereas global inspection required establishing conceptual relations based on an overall analysis of structure. Similarly, the benefits of the argumentative diagram in an open domain may only arise when students recognize its overall structure. It is in relating different arguments that co-construction and transformation of knowledge can take place. Therefore, it is also important to know whether students use the representations together or individually. While individual use of an argumentative diagram might lead to a simple accumulation of arguments, collaborative use can lead to conceptual change (see for example Roschelle, 1992, on convergent conceptual change). Our third question therefore aims at a qualitative exploration of what students actually *do* with the representations when exploring the space of debate. We inspect when students look at representations, what they do with it, and what they say about it to their partner.

The present study addressed all three aforementioned questions. We examined the quality of an open-ended discussion in terms of breadth and depth of the space of debate, and related this to the use of external representations. More specifically, we (i) compared a text and a diagram that students individually constructed before and after discussion, (ii) compared the collaborative use of a diagram students constructed themselves with a diagram that was made for them by the researcher based on students' own text, and (iii) investigated how students actually used these representations during collaboration.

The differences between texts and diagrams in terms of linearity, space, and ability to indicate relations could lead to different processes of broadening and deepening the space of debate. A diagram may be a good tool to broaden the topic under discussion, while a textual representation may lead to more deepening it in detail. The given diagram may lead to the broadest and deepest discussion, because students benefit from both linear detail they wrote in text, and structure and relations shown in the given diagram. However, if construction is more important than the modality of the representation in itself, students do not benefit from this given diagram.

Method

Participants

Students from seven classes in four upper secondary schools (pre-university) in the Netherlands participated (N=195). These schools volunteered to participate after a survey answered by 77 schools (Deliverable 8, SCALE-team, 2002). The students were 15 to 18 years old. A questionnaire given before intervention showed that collaboration in groups of two or more students was a fairly common practice, as was (individually) writing an argumentative text; students indicated having done this at least 1 to 5 times in the previous year. Seventy five percent of the students used computers to chat to other people, but not in school tasks. Half of the students indicated experience with collaborative work via the computer for school, but the other half said they had no experience with group work on the computer. Students were randomly divided into three groups according to condition (text *T*, diagram *D*, or given diagram made from text *TD*), and were put in dyads of students who differed in viewpoints and/ or arguments. Due to absenteeism, the number of dyads that were actually available for analysis (N= 58) is much smaller than the total number of dyads (N= 96). Dropout rates are about equally divided across conditions.

Design of the study

We used a collaborative writing task consisting of three phases (see Figure 1). The study included between-group differences in constructed representations before discussion (text T, diagram D), and in inspected representations during discussion (text T, diagram D, given diagram made from text TD). Representations were compared within groups (comparing individual representations from phase 1 with revise representations from phase 3). In phase 2, students discussed via chat and wrote an argumentative text together. The goal of writing gives direction and meaning to the discussion and may further broaden and deepen the space of debate.

Note that the given diagram made by the researcher (TD) was based on students' own ideas. It is a diagram made from the text students wrote themselves, not a diagram made on an expert's ideas to show the 'perfect' space of debate. In order to investigate differences in construction versus inspection of diagrams for learning, the diagrams should be comparable in terms of structure and content. Therefore, the given diagrams represent learners' own ideas instead of an expert's ideas.

Computer-based activities	*Condition D*	*Condition T*	*Condition TD*
Phase 1 *Individual preparation:* Students read sources and construct either text or diagram			
Between phase 1 and 2 Researcher constructs diagrams from texts in TD condition			
Phase 2 *Discussion and collaborative writing in dyads*: Dyads chat and write text collaboratively while their two individual diagrams (D), texts (T) or diagrams made from texts (TD) are available for inspection			
Phase 3 *Individual consolidation:* Students revise their own diagram or text from phase 1			

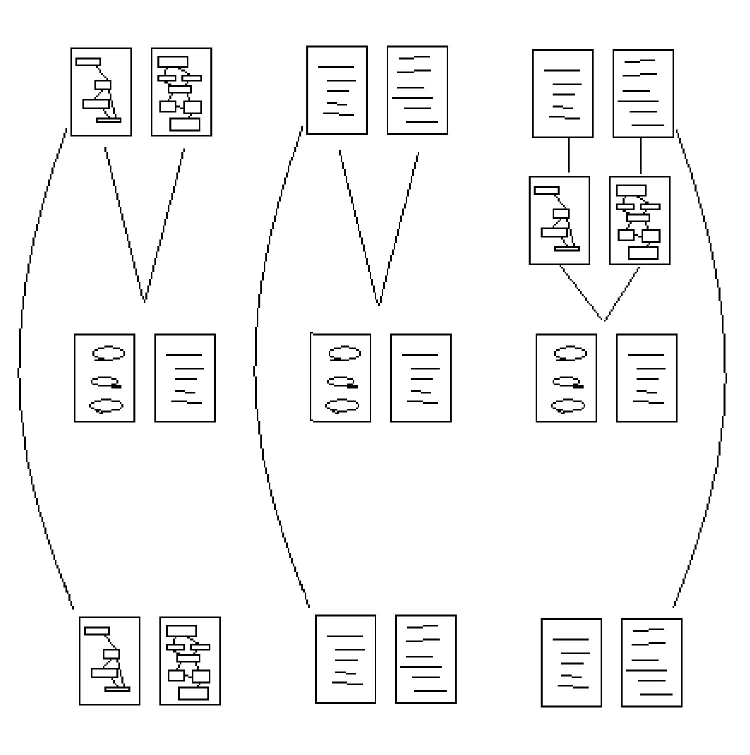


Figure 1. *Design of the study*

Computer environment

The computer environment that was used is *TC3*, developed at the Department of Educational Sciences in Utrecht to support collaborative argumentative writing in dyads (Jaspers & Erkens, 2000). For the present study an individual and a collaborative version of TC3 was developed.

When the individual version of TC3 was started, a user saw three windows: a chat window, (disabled), a window to write a text, and an information window.

Extra feature was a diagram (Figure 2), which popped up when the *diagram* button was clicked. The information window consisted of nine tabs containing the task assignment, a manual, criteria for assessment, and six information sources on the topic of genetically modified organisms (GMOs[6]). In the individual version students used either the text window or the diagram, depending on the condition they were in.

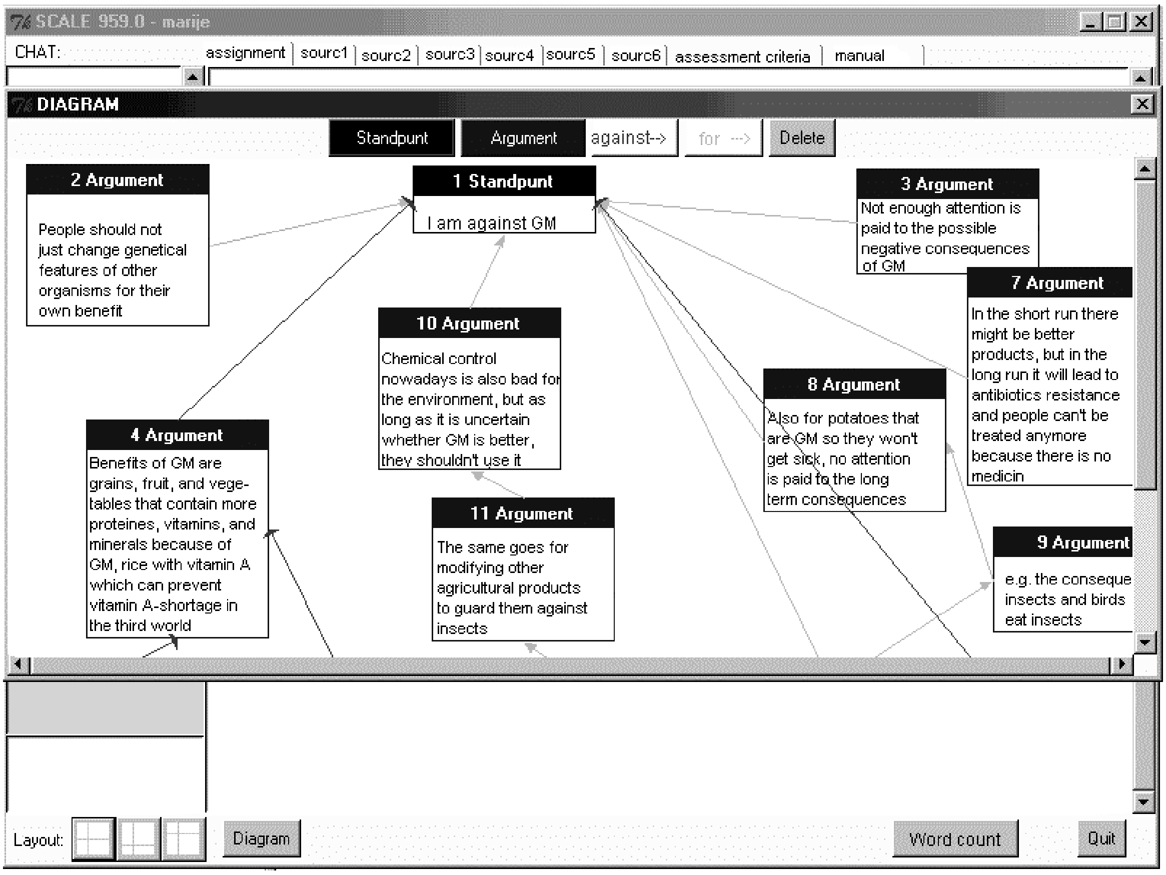


Figure 2. *An example of a diagram in the individual version of TC3 (translated from Dutch to English)*

The main windows in the collaborative version were the same as in the individual version of TC3 (chat, text, and information, see Figure 3). Students needed a number to log on, which enabled the program to link two computers. The chat window (1) could then be used to chat with the partner the student was linked to. It had three parts: below, a student could type his/her lines, in the middle part one could see what the other one was typing, and at the top the chat history was shown. The chat history was saved for all sessions. The text window

[6] We searched for information about GMOs on the Internet, in newspapers, and in magazines. Sources were chosen that reflect diverse standpoints and arguments. For more information on the selection procedure of the information, see SCALE report, Deliverable 1 & 2, 2002.

(2), used for collaborative text writing, could only be accessed in turns. Turn taking was done by using the traffic light (4). The information window (3) did not contain information sources on GMOs anymore, because we wanted students to make use of the information they put in their individual representations instead of the information in the official sources, to see what they thought was important themselves. The TC3 manual, information on the assignment, and assessment criteria were still available. Students had access to individually made texts or diagrams to look at their own standpoint and arguments or see their partners' representation. The representations were shown when clicking the buttons at the lower bar (5). All these windows could be accessed at all times, there was no specific order in which the task had to be carried out. Students could see on their own screen when their partner was writing chat or writing text, but not when their partner was looking at the representations or the task information. There was no shared pointer to refer to things; students could only refer in language. The boxes in the diagram are numbered for easy reference.

Procedure

The study consisted of six sessions of 50 minutes. Students were asked to discuss and write about the controversial topic of genetically modified organisms (GMOs). Since the topic of GMOs and argumentation are both part of the curriculum in upper secondary education, the experiments could be conducted during (six) regular hours in classes of Dutch language or Biology.

The six sessions were divided in three phases: (1) The individual preparation phase, about 80 minutes long; (2) the discussion and collaborative writing phase, about 150 minutes long; and (3) the individual consolidation phase, about 30 minutes long.

In the first phase, students gained initial knowledge on the issue of GMOs by reading information sources. They formed their opinion, supported with

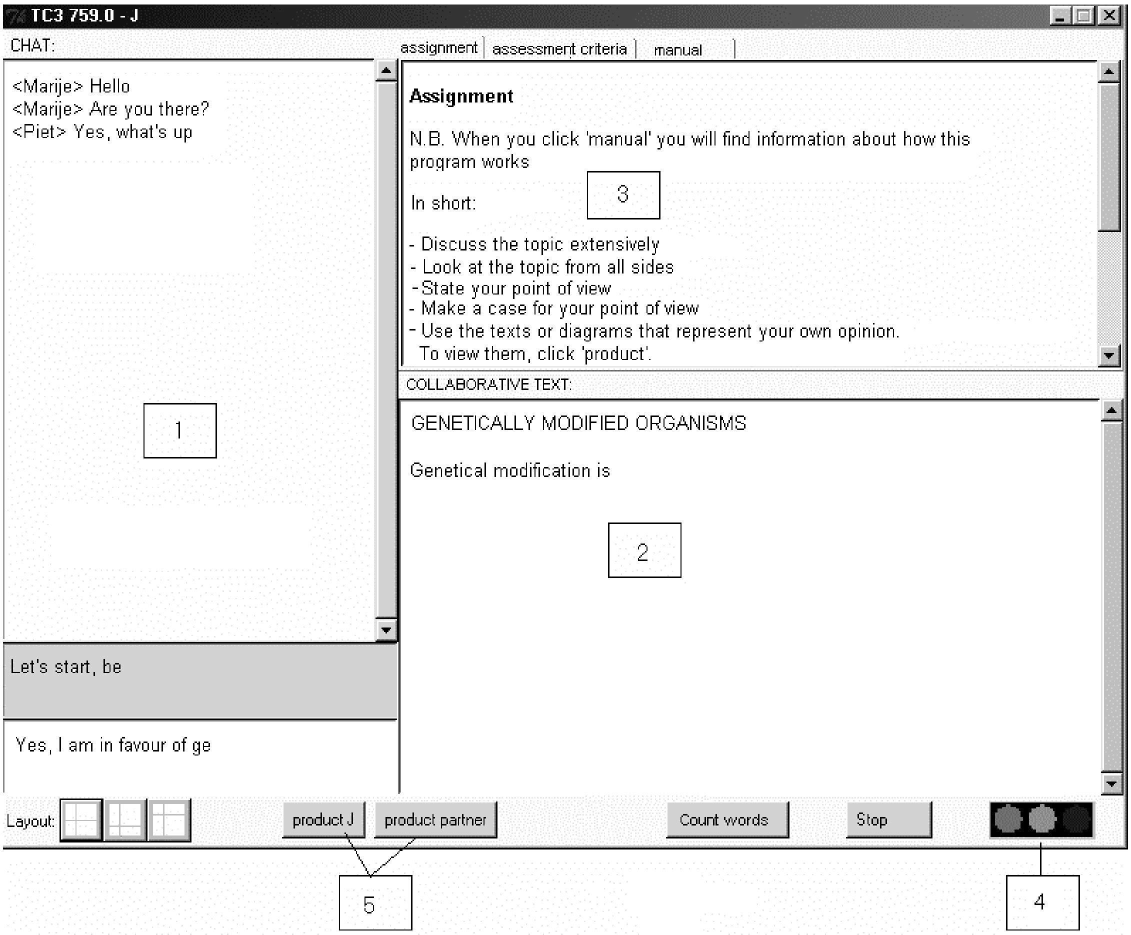


Figure 3. *Screen dump of the collaborative version of TC3 (translated from Dutch to English)*

arguments and counterarguments, and put that in a diagram or text.

Between the first and the second phase the researchers formed dyads of students based on the individual representation that the students had constructed in phase 1. Students with different opinions and/or different arguments were put together in order to provoke discussion between students with different ideas on GMOs. Not all dyads were comparable in terms of breadth and depth of the individual representations, but there were no differences in (un)equality of dyads across conditions.

For the given diagram condition TD, the researchers constructed diagrams of the texts students wrote. Diagrams contained sentences from the texts in boxes, and linguistic markers were used to construct arrows. Sentences in text were summarized in diagram to fit the boxes. Appendix A shows an example of a text that was represented in a diagram (translated from Dutch into English).

In the second phase, dyads chatted about GMOs and wrote an argumentative text together reflecting their opinion. Information sources were thus not available anymore, but two individual texts, two diagrams, or two diagrams made by the researcher of the texts were.

In the third phase, individual students went back to their individual diagram or text and revised these to represent what they thought and knew about the topic after debate.

Methods of analysis

The process of collaborative discussion and writing was analysed with MEPA (Multi Episode Protocol Analysis, Erkens, 2001). MEPA automatically divides the protocol in separate activities. The chat is separated by students pressing <Enter>; the text is separated by students taking turns. Every push on a button is separately logged, and the log file can be used to replay the whole process. The unit of analysis for chat followed MEPA's division of activities, except where students cut their sentences in chat or put different argumentative moves in one sentence. In phases 1 and 3, we did not analyse the process but only the product of the phase. The unit of analysis for the individually constructed texts and diagrams was a sentence, except when students put more argumentative moves in one sentence.

Rainbow. The Rainbow framework (Baker, Andriessen, Lund, Van Amelsvoort & Quignard, 2006), developed in the SCALE project, defines students' general collaborative activities in seven categories. These seven categories distinguish task-related activities (categories 4-7) from non-task related (categories 1-3) activities, and argumentative activities (categories 5-7) from non-argumentative activities (categories 1-4). A description of each of the categories can be found in Table 1. Together, they reflect the richness and diversity of a real-life discussion in a certain task environment. The categories can only be applied in their context, because activities derive their meaning within the collaborative process. The framework is descriptive, not normative, and provides information on both frequencies and sequences of activities. Because the categories are indicated with the seven colours of the rainbow, the sequence of activities can be easily viewed visually in an analysed protocol. Moreover, the Rainbow framework can be applied to all activities students carried out in the collaborative environment, revealing the mix of activities in chat, writing, representations and computer environment. Inter-rater agreement on ten protocols was .82 (Cohen's Kappa).

Table 1. *Rainbow categories*

Rainbow category	Explanation	Example
1 Outside activity	all interactions that do not have anything to do with the task	"How was the party yesterday?"
2 Social relation	all remarks about the social relation	"You are doing well!"
3 Interaction management	all remarks about communication, like checking presence, checking understanding	"Hello, are you there?"
4 Task management	all remarks and actions for managing the task	"It's your turn to write now"
5 Opinions	all statements about students' opinions	"I am in favour of GMOs"
6 Arguments	all arguments and counter-arguments students use to support or rebut a statement	"Because of Genetically modified food hunger in the third world will be banned"
7 Explore and deepen	all remarks that explore and deepen the (counter)arguments	"but hunger in the third world is not due to lack of food in the world, but to unequal division of food"

Breadth and depth of the space of debate. While Rainbow tells us about general activities in chat and writing, breadth and depth of the space of debate tell us about the extent to which the topic is explored. Breadth and depth of the space are based on categories five, six and seven of the Rainbow framework, because these categories comprise argumentative content. This is done firstly because we wanted to elaborate upon students' argumentative activities, the main concept in our studies. Secondly, the analysis of breadth and depth of the space of debate can be applied to both the individual representations and the collaborative discussion and writing, enabling us to view development of the space of debate in the three phases. The Rainbow framework, in contrast, was developed for the processes of collaborative activities only.

The *breadth* of the space of debate was defined as the amount of topics and subtopics mentioned. The debate on GMOs includes a variety of epistemological points of view (biological, agricultural, political, economical, ethical), and a variety of social actors in the debate (grain producers, researchers, citizens, farmers, politicians, non-governmental organizations). When students broaden the space of debate, they look for example at GMOs from the view of Greenpeace, but also from the view of the government, or they move from talking about consequences of GMOs for health to consequences for the environment. We distinguished five main topics in the GMOs issue, namely health, environment, affluence, worldview, and other. These topics were further divided into fourteen subtopics (such as affluence-hunger/food; affluence-costs/benefits). Inter-rater reliability of breadth between two judges was .75 (Cohen's Kappa).

When students talk in *depth* about the topic under discussion, they relate different concepts, and elaborate upon their arguments. For example, students do not only say that GMOs are bad for the environment, but also argue why this is the case, and give an example. For the analysis of the depth of the debate, a scoring system was developed in which all content-related utterances were analysed in their immediate context. The scheme consisted of four categories that received different weights: 1) stating an argument, 2) giving an example or explanation of an argument, 3) stating a support or rebuttal, and 4) explicit explanation of a relation between different arguments. We looked at episodes of content-related activities. For example, a support or rebuttal could only be scored if an argument is scored first. In the statistical analyses these categories were used separately. Hence, there were four scores that students could get for depth. However, because deepening the space of debate is shown by a line of argument, we also look at the total depth in which the scores on the separate categories are added. Table 2 gives an example of a scored protocol. The interrater reliability of the depth of the space of debate was .77 (Cohen's Kappa).

Table 2. *Example of scoring breadth and depth of the space of debate*

Content of argument	Who	From where	Breadth	What happens	Depth
I am pro, because it is good for the 3rd world, they can use extra vitamins	Maria	own diagram	Health-nutrients	argument and explanation	1+2
No, the 3rd world cannot afford GM, it is only meant for the rich West, and then nobody will buy products from the 3rd world anymore	Tom	new	Affluence-division	rebuttal, explicit relation and explanation	3+4+2
But the rich countries will help the poor countries with money and funding	Maria	new	Affluence-division	rebuttal and explanation	3+2
That happens already (funding), but with GMOs nobody will buy things from the 3rd world and they will become even more poor	Tom	new	Affluence-division	rebuttal and further explanation of argument #2	3+2
					22

Use of individual texts and diagrams during collaborative phase. The representations text, diagram and given diagram made from text are available for inspection during the second phase of discussion and collaborative writing. The analysis presented here addresses the third research question of how these representations are used by the students in collaboration. We as researchers and developers may have ideas on how representations should be used, but that may not be what students actually do. Students can use the representations in a local way (i.e., to copy elements), or in a more global way (i.e., as a starting point for a constructive discussion that leads to constituting or transforming knowledge). More specifically, we distinguished seven ways in which students used the representations during the collaborative phase: (1) to look at each other's representation and compare; (2) to remember own opinion or arguments; (3) to copy, to find arguments, as a source of information; (4) as a trigger to talk or write about; (5) as a starting point, followed by individual construction of new or transformed knowledge; (6) as a starting point, followed by collaborative construction of new or transformed knowledge; (7) unclear. These seven ways of using the individual representations were derived from the protocols, by looking at what students actually did during chatting and collaborative text writing. Like the other two analyses, this analysis can only be derived in its context. For example, the protocol shows that a student first clicks the button to view her own representation, then the button to view her partner's representation, and then chats: 'We are both in favour of GMOs'. This episode can then be categorized as (1).

Results

The description of the results follows the task phases. First we describe the individual breadth and depth of texts and diagrams in phase 1. Then we look at how dyads work in the collaborative chat and text writing (phase 2). In phase 2, we also take a more in-depth look in how students have used the representations in their exploration of the topic of genetically modified organisms. Finally, we look at the breadth and depth of texts and diagrams in phase 3, and their improvement over time.

Phase 1: Individual construction of Text or Diagram

Our first research question dealt with differences in breadth and depth of two types of constructed representations: texts and diagrams. Students individually constructed either text or diagram in phase 1. We conducted independent-samples t-tests on the breadth and depth scores between text and diagram conditions. There were no significant differences in *breadth* of the space of debate between texts and diagrams, $t(58) = 1.20$, $p > .05$. Results also showed no significant differences for any of the measures of *depth* (arguments, explanations/examples, supportives/rebuttals, explicit relations). In short, our expectation that diagrams would be broader, and texts would be deeper was not confirmed. This means that students in both conditions started their collaborative phase 2 with similar individual spaces of debate.

Phase 2: Collaborative discussion and text writing

The second research question was aimed at understanding differences in exploration of the space of debate when students had a text, a diagram, or a given diagram available for inspection. We first analysed the collaborative discussion and writing (i.e., phase 2) with the Rainbow framework to characterize the activities students performed in general. From these general activities, we isolated the argumentative content actions and analysed them on breadth and depth of the space of debate.

Activities in chat and writing in dyads: Rainbow. Results of Rainbow analyses are shown in Table 3. A one-way ANOVA was performed on the means of the Rainbow categories between the three conditions. We did not find significant differences for any of the Rainbow categories. Only Rainbow category 5 'Opinions', $F(2,27) = 3.17$, $p = .06$, showed an almost significant difference; the percentage of opinions in the text-condition was higher than in the other two conditions. Therefore, we talk about the means of percentages over all three conditions (adding and dividing the three columns in Table 3) in the remainder of this section. Overall, less than 4% of students' activities were outside activity, indicating that they were focused on the task. Most striking in the results was the fact that students invested a large amount of their activities (66%) in managing the task, specifically the writing task. For example, the students discussed who was to write, counted the words of their text, looked at their individual texts or diagrams, or worked on structure or spelling of the text. About 16% of all activity was spent on content interaction (categories 5, 6, and 7), chatting and writing about GMOs. This percentage is consistent with findings in other argumentative tasks (e.g., Veerman, 2000; Van Boxtel, 2000).

Table 3. *Mean frequencies (with standard deviations) and percentages of Rainbow categories*

Category	*Text*		*Diagram*		*Given diagram*	
	Mean Frequency (SD)	*Percentage*	*Mean Frequency (SD)*	*Percentage*	*Mean Frequency (SD)*	*Percentage*
1 Outside activity	6.40 (7.09)	1.2	23.10 (33.96)	4.6	30.40 (26.74)	5.4
2 Social relation	21.50 (18.86)	4.5	18.20 (10.68)	4.0	31.00 (31.50)	5.0
3 Interaction management	46.80 (29.07)	9.6	47.70 (19.36)	10.1	49.00 (30.94)	9.0
4 Task management	298.30 (102.12)	65.0	318.10 (88.72)	67.5	341.70 (102.32)	66.4
5 Opinions	27.50 (8.91)	6.5	18.00 (6.87)	3.9	24.00 (10.00)	4.7
6 Argumentation	19.20 (8.46)	4.5	20.00 (10.36)	4.2	17.50 (7.88)	3.7
7 Explore and deepen	35.40 (20.66)	8.8	25.10 (12.63)	5.7	29.50 (17.15)	5.7
Total	455.10	100	470.20	100	523.10	100

Content related argumentative interaction in chat and writing. ANOVAs of breadth and depth in the collaborative phase showed a significant difference between dyads in the diagram and text condition for both *broadening,* $F(2,27) = 5.82$, $p < .05$, and *deepening,* $F(2,27) = 3.48$, $p < .05$, the space of debate. Post hoc tests indicated that dyads broaden more in the diagram condition than in the text condition and the given diagram condition, and also deepen more in the diagram-condition than in the given diagram condition. The text condition did not differ from the diagram and the given diagram conditions on deepening the space of debate. The significant difference in depth was due to a difference in examples and explanations, $F(2,27) = 7.96$, $p < .05$, with the diagram being deeper ($M = 18.4$; $SD = 5.9$) than the text ($M = 11.6$; $SD = 4.9$) and the given diagram ($M = 10.2$; $SD = 3.8$).

In short, students in the diagram-condition broadened and deepened the most. The given diagram condition did not benefit from constructing text and inspecting diagram. Students in the given diagram condition broadened and deepened the space of debate less than the dyads in the other conditions.

Broadening and deepening the space of debate in the collaborative phase 2 was done via chat and via collaboratively writing the argumentative text, both in different windows. We therefore split chat and writing (see Figures 4 and 5). Correlations are not significant between chat and text in either breadth ($r = -.25$, p

> .05) or depth (M_r = .13 on depth-measures separately, $p > .05$), indicating that there is no straightforward relation between dyads' exploration in chat and in collaborative writing.

In *chat*, a trend towards significance for *broadening* the space of debate in chat, F (2,27) = 3.07, $p = .06$, is seen, with dyads in the diagram condition broadening the most (M_{chat} = 8.8; SD = 2.4), and dyads in the given diagram condition broadening the least in chat (M_{chat} = 6.1; SD = 2.6). There is no significant effect in chat for *deepening* the space of debate between conditions, F (2,27) = 510.63, p >.05.

In *collaborative writing*, there is a trend towards significance for *broadening* the space of debate, F (2,27) = 2.94, $p = .07$, with dyads in the diagram-condition broadening the most ($M_{writing}$ = 9.5; SD = 1.4), and dyads in the text-condition broadening the least in writing together ($M_{writing}$ = 7.6; SD = 2.0). For *deepening*, a significant effect between conditions was found, F (2,27) = 1022.43, $p < .01$. Students in the diagram-condition (M = 10.9, SD = 2.2) use significantly more examples and explanations than students in the text-condition (M = 5.7, SD = 1.8) and the given diagram condition (M = 5.4, SD = 1.9), F (2,27) = 24.04, $p < .01$. The number of arguments used in writing shows a trend toward significance, with the diagram condition deepening with more arguments (M = 11.9, SD = 5.5) than the given diagram condition (M = 8.5, SD = 3.9) and the text condition (M = 8.0, SD = 2.4), F (2,27) = 2.66, $p = .09$. Figures 6 and 7 display the subcategories for depth and breadth separately in chat and in writing.

To summarize, dyads in the diagram-condition deepened their collaborative writing more than dyads in the other two conditions, mainly due to the amount of explanations and examples they use. Although the difference in broadening is not significant, the effect sizes are high, indicating that this difference might become significant with a larger sample size. Students in the given diagram did not benefit from both text-construction and diagram-inspection; they never score higher than the other two conditions on either breadth or depth of the space of debate.

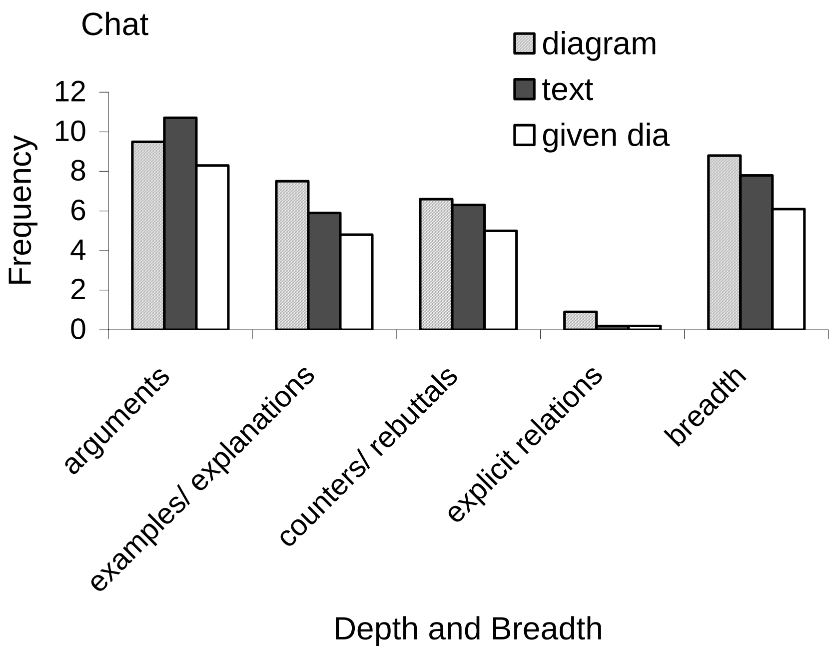


Figure 6. *Frequencies of depth and breadth in chat, split for the three conditions*

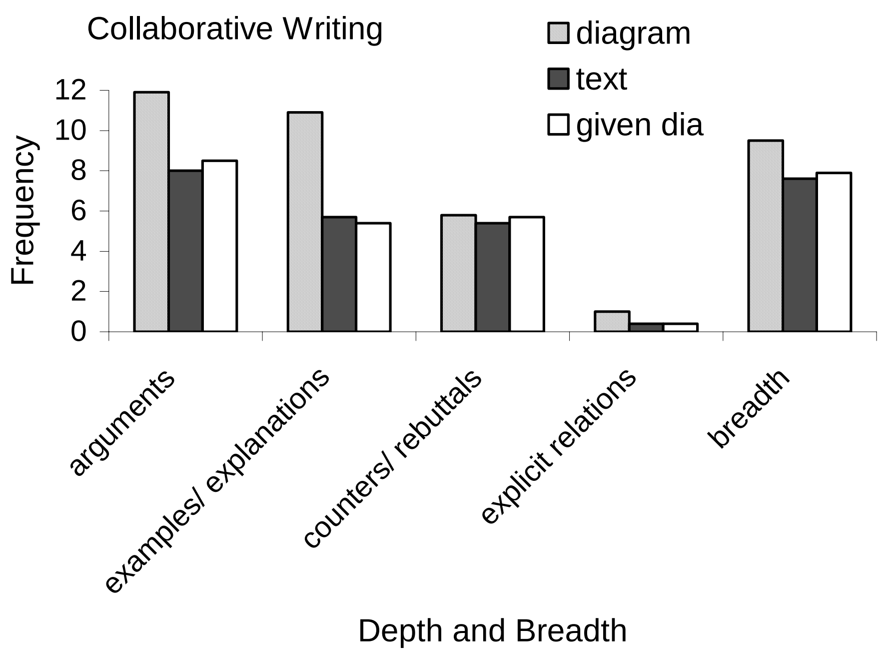


Figure 7. *Frequencies of depth and breadth in collaborative writing, split for the three conditions*

<u>*How students use the representations in exploring the space of debate*</u>. The third research question was concerned with variations between dyads in how they used the representations in their collaborative effort to broaden and deepen the space of debate. As can be seen from the results described above, standard deviations are rather high. This means that there are substantial differences between dyads in one condition. In this section a qualitative exploration of different types of dyads is presented in order to illustrate the sources of variation in the use of representational tools.

When we take a closer look at the differences in broadening and deepening for each dyad, three types of dyads can be distinguished. Some dyads broaden and deepen the space of debate very much in chat, compared to their individual representations, but not in writing. We call these the 'Mountains', because their broadening and deepening scores can be visually represented as a mountain 'Λ', namely relative low score on individual representations, high score in chat, and low score in collaborative writing. For other dyads the opposite is true (the 'Valleys', 'V'), and a third group of dyads shows a shallow individual representation, followed by a somewhat broader and deeper chat, and an even broader and deeper collaboratively written text (the 'Rising Slopes', '/'). Figure 8 displays scores of a Mountain, Valley and Rising Slope pair to visually show how they received their name. The scores of all dyads can be found in Appendix B. Two dyads could not be classified. From Appendix B it can be seen that the Rising Slopes are found more in the diagram condition (5 times) than in the other two conditions (2 and 3 times), the other types are about equally divided over conditions. Note that chat and collaborative writing can be done in parallel; students do not have to use chat first and text later.

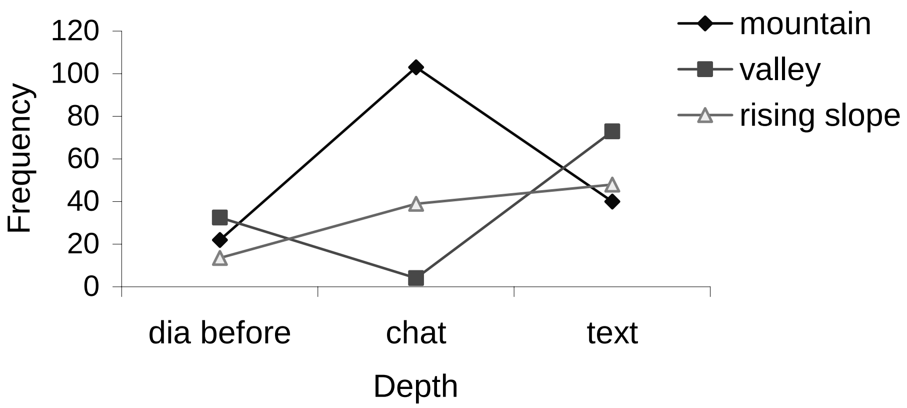


Figure 8. *Visual display of a mountain, a valley and a rising slope strategy*

Below, an example is given of a dyad that can be defined as 'Mountain' (text condition). After exchanging greetings, and some first exchanges of viewpoints, they chat:

Joleen	why are you in favour?
Mary	because I think it could solve a lot of problems in the world, e.g. famine *(telling from own individual text)*
Mary	I think it is not necessary in the West, we already have enough *(new)*
Joleen	And little farmers won't have any chance when gm-food is made by other companies *(telling from own individual text)*
Mary	Indeed, I also think we should still have natural food *(telling from own text)*
Joleen	Indeed, gm is ok, but there are boundaries *(telling from own text)*
Mary	It is important that it is safe for humans *(new)*
Mary	You shouldn't be dying after eating gm-food *(transforming)*

From this excerpt, all done in chat, it can be seen that students explore their space of debate in chat. Mary answers Joleen's question first with an opinion that she already put in her individual text, but then elaborates on her own opinion with a restriction that GMOs would not be necessary in the West. Joleen implicitly agrees with her on restrictions by giving another argument against GMOs. Giving arguments from the two individual texts combined with elaborations and transformations, these two students negotiate a joint standpoint with arguments in chat that they later put almost exactly in their collaborative text. The beginning of their collaborative text is displayed below:

> We are in favour of genetic modification, if we keep boundaries.
> We think that especially in the West genetic modification should not be used, because we already have more than enough here. Here in the West we often have food in abundance, so genetic modification wouldn't help us.
> In the third world, genetic modification can be a solution to famine. …

The next example is an example of a 'Valley' (given diagram condition). This excerpt displays the start of their collaboration. Note the immediate focus on writing the text:

Bill	Hi Colin, let's write!
Bill	You were against, weren't you?
Colin	I am against applications that haven't been researched yet. I am in favour of applications that have proved to be useful *(telling from own individual diagram)*
Bill	Me too
Colin	See Colin's product
Bill	*writes in text:* We are in favour of GMOs, only if the applications have been researched and proven *(telling from chat and partner's diagram)*

These two excerpts of chat and writing are typical of their categories. Valley-dyads are focused on writing; they see the collaborative text they have to write as the goal of the task. Chat is used mostly to manage the writing task. For example, the dyad from the excerpt above was aimed at managing the task (Rainbow category 4) in chat 86% of the time. Only 6 % of their chat was aimed at argumentative interaction (Rainbow categories 5 to 7). The Mountain-dyads are much more focused on exploring the space of debate before they start writing. However, their collaborative text is not as broad and deep as their chat. A Rising Slope-dyad shows characteristics of both Mountains and Valleys, some focus on discussion in chat, and some focus on broadening and deepening in text.

How are individual representations used in phase 2, the discussion phase? While students are discussing and writing together, they have access to the individual texts or diagrams they made. We logged frequency and timing of students looking at the individual representations. Unfortunately, due to an error in the logfiles, we cannot be certain which representation is a students' own, and which is their partner's. However, we can distinguish between the two representations. During collaboration, students looked about 16 times at one representation, $M = 15.67$, $SD = 12.03$), and 18 times at the other representation ($M = 17.67$, $SD = 11.74$), for about 20 seconds at a time. An ANOVA revealed no overall differences in how often, $F\ (2, 27) = .39$, $p > .05$, and how long, $F\ (2, 27) = 1.13$, $p > .05$, students looked at the individual representations between conditions. However, when distinguishing Mountains, Valleys and Rising Slopes, dyads defined as Mountains checked their individual representations significantly fewer times ($M = 23.0$; $SD = 18.2$) than Valleys ($M = 44.5$; $SD = 16.1$) and Rising Slopes ($M = 46.2$; $SD = 24.3$), $F\ (2, 23) = 3.78$, $p < .05$.

Dyads defined as Mountains, Valleys, or Rising Slopes do not only differ in frequency of using their individual representations, but also in the way in which they use these representations during the collaborative phase. In chat, Mountains as well as Rising Slopes used the individual representations more often than Valleys as a starting point for discussion, leading to a constructive collaborative discussion ($M_{\text{mountains}} = 1.7$; $M_{\text{risingslope}} = 1.5$; $M_{\text{valley}} = 0$). In writing together, Mountains showed less telling from individual representations than Valleys or Rising Slopes ($M_{\text{mountains}} = 0.7$; $M_{\text{risingslope}} = 4.3$; $M_{\text{valley}} = 3.7$). Mountains made less use of the individual representations during writing overall ($M_{\text{mountains}} = 1.7$; $M_{\text{risingslope}} = 6.5$; $M_{\text{valley}} = 5.7$).

Below, some examples are given of how students use the representations while they are discussing the topic of GMOs. The first excerpt (diagram condition, valley) is an example of how students use the individual representations to remember their viewpoints and arguments, and compare their representations. They first look at the diagram they made individually, and check their partner's representation. Then they start discussing each other's work. This often happens at the start of the collaborative phase, or at the start of a new lesson.

Vincent and Katie both start with looking at each other's diagram, then chat:	
Katie	Your point of view is neither for, neither against *(deduction from partner's diagram)*
Vincent	Yours is definitely in favour, wait, I'm going to read it carefully *(deduction from partner's diagram)*
< *Vincent opens Katie's diagram* >	
Katie	Ok
< *Katie opens Vincent's diagram* >	
Vincent	Your text* is good, how is mine?
Katie	Also good, but I think you are more in favour than against
Vincent	Yes, that's right
Vincent	Then let's write a text that is pro, but also has some aspects of against
Katie	A little in favour, a little against
Vincent	exactly
	…
Katie	Uhm…GMOs are good for society? (*transforming*)
< *Vincent opens own diagram, Katie opens Vincent's diagram* >	
Vincent	Genetic modification of food is good, as long as there are no harmful consequences? (*telling from own diagram*)

* Vincent refers to Katie's diagram as text.

Sometimes, the individual representations can give rise to a discussion that moves beyond what is written in the representations; it leads to an elaboration of ideas and arguments. In the discussion, this is mostly a collaborative activity, while during collaborative text writing, the elaboration is also often done by the individual who is writing. In the example below, Aisha and Odin exchange greetings first, and then spend some time looking at both individual representations. Then Aisha summarizes their two individual given diagrams by saying that she thinks they agree. Odin agrees with her finding, but then elaborates on his own ideas with a more subtle opinion that he didn't mention in his representation. This gives rise to new arguments, such as the one from Aisha at the end of the excerpt:

Example (given diagram, Mountain):

< *After exchanging greetings and looking at both individual representations:* >	
Aisha	I think we agree for a large part
Odin	indeed
Odin	Actually, I'm both in favour and against *(new)*
Aisha	How?
Odin	I think we should adjust our food production to the world population, or even more people will die from hunger *(telling from own diagram)*
Aisha	Exactly, but we cannot use it to make it easy for ourselves *(new)*

During text writing, individual representations are often used to find arguments and put them in the collaborative text, more or less literally. Students also occasionally look at the individual representations when their partner is writing, communicating found arguments to the other person by chat, or using them later when they write a part of the collaborative text.

Example (text, slightly Rising Slope):

After almost an hour of collaborating, Nelly is writing the introduction of the collaborative text, while Kim is looking at her individual text	
Kim	Shall I write something about diversity? *(topic from her individual text)*
Nelly	I'll do that, so you can look at my introduction and finish that

In summary, our qualitative analyses show that three strategies can be distinguished in collaborative argumentation-based learning, namely Mountains, Valleys and Rising Slopes. These strategies determine how dyads of students use representational tools. Students who display a deep discussion in chat (the Mountains and Rising Slopes) use their representations mostly to start a co-constructive discussion, while students who display a shallow discussion in chat (the Valleys) mostly copy information from their representations directly in their collaborative text.

Phase 3: Individual revision of Text or Diagram

In phase 3, after discussion, students revised their individual text or diagram from phase 1. We first compare texts and diagrams in the third phase. Then we compare the revised representations from the third phase with the constructed representations from the first phase, to get an indication of individual learning. Table 4 presents the means and standard deviations for breadth and depth of texts and diagrams in the first preparation and the third consolidation phase.

Table 4. *Means (with standard deviations) of breadth and depth in individual representations*

Phase	**Type**	**Text**		**Diagram**	
		M	*(SD)*	*M*	*(SD)*
Phase 1: Individual preparation	Breadth	5.9	(1.9)	6.4	(2.1)
	Depth 1	6.5	(2.8)	5.7	(1.8)
	2	2.0	(1.3)	3.6	(2.3)
	3	4.0	(2.3)	3.1	(2.4)
	4	0.3	(0.6)	0.0	(0.0)
Phase 3: Individual Consolidation	Breadth	6.8	(2.1)	7.6	(1.7)
	Depth 1	7.6	(3.1)	8.3	(2.0)
	2	3.4	(1.8)	4.2	(2.3)
	3	4.4	(2.6)	3.5	(2.2)
	4	0.3	(0.7)	0.1	(0.2)

Note 1. Depth: 1= arguments; 2= examples and explanations; 3= counters/rebuttals; 4= explicit relations

Note 2. No significant differences between Text and Diagram conditions

<u>*Texts versus Diagrams in phase 3*</u>. An independent-samples t-test revealed no differences in *breadth* of the space of debate between the diagram and the text condition after discussion, $t(57) = 1.55$, $p > .05$, nor in *depth* of the space of debate. This means that there was also no difference between texts and diagrams in breadth and depth of the space of debate after discussion.

<u>*Learning with texts or diagrams*</u>. Comparison of the revised representations after discussion with the constructed ones before discussion gives us an indication of what individual students have learned from discussion and collaborative writing, and whether the format of the representations has an effect. To examine the effects of the format of the representations on learning, an ANOVA was performed on the diagrams and texts made before and adapted after discussion. The design of the analysis was format (diagram, text) as a between-subjects factor, with repeated measure of time (before discussion, after discussion). Analysis revealed a significant effect of time, $F(1, 57) = 45.54$, $p < .001$, for *breadth*, indicating that all students had broadened their space of debate after discussion. However, there was no interaction with format, $F(1,57) = 0.61$, $p > .05$. There was also a significant effect of time, $F(1, 58) = 60.83$, $p < .001$, for *depth*, indicating that all students deepened their space of debate after discussion compared to before discussion (see Figures 9 and 10). A significant interaction with condition, $F(1, 58) = 4.07$, $p < .05$ was found. This was due to a significant difference in number of arguments. Before discussion, the number of arguments was lower in the diagram condition than in the text condition ($M_{textbefore} = 6.45$; $M_{diagrambefore} = 5.65$), but after discussion this relationship was reversed ($M_{textafter} = 7.63$; $M_{diagramafter} = 8.25$). To interpret the size of the difference, we used Cohen's *d* (1988) to calculate difference scores before and after discussion in both conditions. Cohen's *d* makes students' scores directly comparable, regardless of individual differences in breadth and depth. We found a mean effect size of 0.95 for depth, and 1.69 for breadth. These scores are considered to be large effects (Cohen, 1988), indicating that students have improved their space of debate considerably. Almost twenty percent indicated a change of opinion in their revised representation.

In summary, all students have learned significantly in terms of breadth and depth of the space of debate. Closer inspection of the representations revealed that they did this by adding boxes or sentences in their representation rather than changing existing texts, boxes or relations. There were no differences between texts and diagrams in the third phase, but students in the diagram condition deepened their knowledge more than students in the text-condition from phase 1 to phase 3.

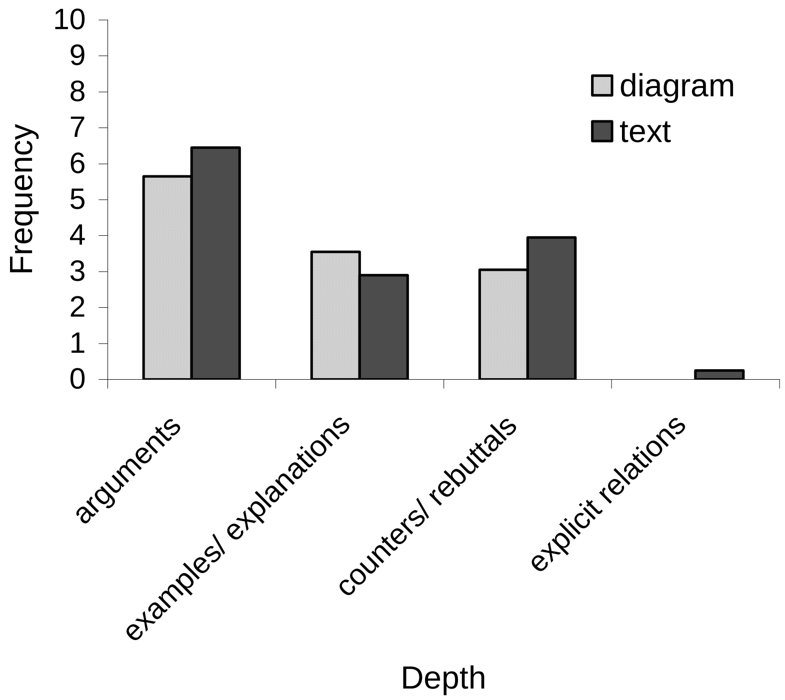


Figure 9. *Frequencies of depth of the space of debate before discussion, split for diagram and text condition.*

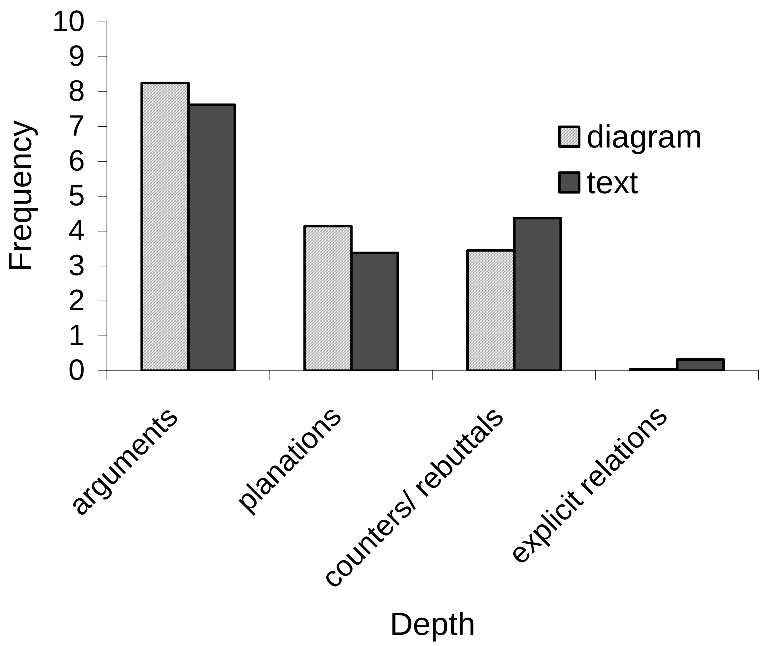


Figure 10. *Frequencies of depth of the space of debate after discussion, split for diagram and text condition.*

Although all students have individually made and revised either a text or a diagram, there was an extra condition of a given diagram made from a student's text by the researcher during the collaborative discussion and writing phase. Working with the given diagram might have affected the revised texts in a different way than working with the self-made texts. Therefore, we also performed an analysis in which the revised texts were split: revised texts from students who have inspected their own text, and revised texts from students who have inspected a given diagram from their text. T-tests showed no significant differences in *depth*, except for the number of arguments, $t(38) = 2.09$, $p < .05$, with the number of arguments in the revised text from the students who inspected their own text being higher ($M = 8.60$; $SD = 2.72$) than from students who inspected the given diagram ($M = 6.65$; $SD = 3.16$). This difference was not present in the preparation phase. The breadth was also significantly different for revised texts, $t(37) = 2.60$, $p < .05$ between students who inspected their own text ($M = 7.55$; $SD = 1.87$) and students who inspected the given diagrams ($M = 5.89$; $SD = 2.11$). Unfortunately, this difference was already present in the preparation phase, indicating an unwanted difference in students' placements into conditions.

In line with our expectations all students learned from the discussion and collaborative writing. We found that the self-made diagrams were deepened more than text after discussion compared to before discussion. This was mainly due to the increase in arguments. Students in the diagram-condition learned the most, and students in the given diagram condition the least ($d_{autodia} = 1.4$; $d_{dia} = 2.0$).

Discussion

This study began with the premise that supporting collaborative argumentation-based learning (CABLE) with diagrams would be beneficial for learning. Research on diagrammatic support for CABLE left us with questions about exactly when and how to use diagrams. Below, several important factors are uncovered to answer these questions.

Diagrams and texts

The benefits of diagrams for CABLE as described in literature have been found in our study. Diagrams have functioned as input for the discussion phase, and gave rise to a broader and deeper discussion. In this sense, they both stimulated and guided CABLE (Suthers, 2003). The diagram students made before discussion helped to maintain focus during discussion (Veerman, 2000). For example, when students were finished talking about one topic, or when they did not know what to write anymore, they looked at their diagram to find something new to discuss or write about. Students also sometimes reflected on alternatives when discussing the representations (Kolodner, 1996). However, all these findings were not only seen with diagrams, but also with text, indicating that the benefits of a diagram for CABLE are generalisable to texts as well.

No differences between diagrams and texts were found in the way students individually explored the topic of GMOs in breadth and depth before they engaged in discussion. The non-linearity of boxes and arrows in a diagram did not lead to a broader diagram, nor did the narrative of text result in a deeper text. The fact that there were no individual differences in breadth and depth between the conditions does make them more comparable for the collaborative phase.

We have to be careful in interpreting the above-mentioned findings. Argumentative diagrams are, unlike most diagrams, verbally oriented, display a lot of information, and are not very spatial (see Lohse, Biolsi, Walker & Reuter, 1994, on classification of visual representations). Although the very essence of diagrams is supposed to ensure a non-temporal, non-causal way of thinking in premises and conclusions, we suggest that students designed the diagram in a narrative way. They focused on the content of the boxes, less on structure of the diagram, or on relations between the boxes. This enhances the similarities between texts and diagrams. Whether it is the nature of argumentative diagrams or students' lack of experience to work with them that causes these similarities needs to be further explored.

The similarity of texts and diagrams in terms of breadth and depth of the space of debate implies that students could write an argumentative text equally well as construct an argumentative diagram when they are asked to individually represent their own space of debate. However, the students who constructed and revised a diagram before and after discussion broadened and deepened their space of debate more than the students who wrote and revised a text. This result implies that students in the diagram-condition have learned more during discussion and writing collaboratively. The discussion about diagrams may have stimulated students to gather more arguments. It may be easier to collaboratively broaden and deepen the topic of GMOs when inspecting diagrams than when inspecting texts, because the diagrams give a quick overview and are easier to compare and refer to. Another possibility is that students in the diagram-condition learned from the translation they had to make from the collaborative text to revision of the individual diagram (Ainsworth, Bibby & Wood, 2002). The cognitive effort that is involved in translation from a collaborative linear text to an individual two-dimensional diagram might have been what triggered learning to take place. The function of the individual constructed representations as inspectable representations during collaboration will be discussed in the next section.

Construction and inspection of diagrams

Construction and inspection of diagrams clearly served different functions in our study. Students constructed diagrams individually in phase 1 to indicate the extent of their space of debate. Although students' knowledge of the space of debate need not be complete in their representation, the activity of constructing an argumentative representation can support and shape students' reasoning (Bell, 1997; Stern, Aprea & Ebner, 2003). The inspection of the diagrams during collaboration in phase 2 supports this finding. Dyads inspected their representations to reason from it. The construction of the diagram thus helps explication and activation of knowledge, while the inspection of the diagram is good to support the discussion.

In this study, students inspected a text or diagram they made themselves, or a given diagram that was made by the researcher from a text they wrote themselves. Students inspected these representations in all conditions as frequently, but the inspection of the self-made diagram led to the most broadening and deepening of the space of debate, especially during collaborative writing (as opposed to chatting together). Sometimes (e.g., in the revision phase, and in chat) the constructed diagrams provide better results than the texts, indicating an effect of kind of representation that is constructed, while other times (e.g., in the collaborative writing task) the constructed diagrams provide better results than the diagrams made for the students, indicating an effect of constructed versus presented representation. Active construction of a diagram is important; the given diagram made from text did not lead to a broader and deeper space of debate. The text students made themselves and the diagrams they received seemed to be two unrelated things for them. Only once in our data did we see a student saying to his partner: "look, they made nice diagrams from our texts!" All others did not talk about the texts being transformed into a diagram. Moreover, the diagrams were sometimes referred to as text ("your text is good, how is mine?"). This indicated a focus on the sentences (content) in the boxes, and not on the structure of the diagram. We will return to this finding below.

Construction of diagrams cannot be easily compared to inspection of (given) diagrams, because the construction was an individual activity, while the inspection was a collaborative activity. In another article, we have compared the two kinds of diagrams in the same task, i.e., construct a diagram together versus inspect a diagram together (Munneke, van Amelsvoort & Andriessen, 2003). We found that the collaboratively constructed diagram led to more task management, aimed at constructing this diagram together. The inspected diagram led to more discussion on opinions, probably because the differences in opinion are clearly visible in the diagrams (Baker, 2003). Students also broadened the space of debate more when inspecting diagrams. However, it is hard to say how construction of a diagram *supports* the discussion, because the discussion is not an activity solely done in chat anymore, but partly shifts to the diagram (Suthers, Girardeau & Hundhausen, 2003; Van Drie et al., 2005).

How students make use of argumentative diagrams

The three representations in our study (diagram, text, and given diagram made from text) did indeed lead to differences in broadening and deepening the space of debate, but different approaches to the task were at least equally important. We identified three kinds of strategies dyads used in their exploration of the space of debate. Mountains had a broad and deep discussion in chat, but not in writing; Valleys had a shallow discussion in chat, but a broad and deep in writing; and Rising Slopes had a medium discussion and a somewhat broader and deeper writing. Difference in strategy proved to be related to difference in the use of the individual representations. Dyads that used their representation as information source for their collaborative text showed a shallow debate. Dyads that used their representations as a starting point for discussion showed a deep discussion, and went beyond what was written in their individual representations to collaboratively construct or transform that knowledge. Apparently, students' strategies interact with the affordances and constraints of different representational tools in determining the extent to which they collaboratively explore the space of debate, irrespective of the format of the representation (although we saw more Rising Slopes in the diagram condition than in the other two conditions).

In general, students' collaborative writing did not differ much in terms of breadth and depth, but the chats were very different. Some dyads discussed GMOs at length, while others used chat only to manage the writing task. Chat seems to be important for the amount and complexity of knowledge construction, but it does not ensure a broader and deeper argumentative text. With chat the topic can more easily drift, not only in analogy, but also because the topics drift off the screen (into the conversation history). With collaborative writing, students constantly work together on the same artefact, which may encourage convergence more. Additionally, in the development of our task we started from the assumption that students first discuss the topic of GMOs in chat, and then write a text about it. We expected that the extent to which the topic was discussed in chat would determine the breadth and depth in text (while also taking into account that writing the text might broaden and deepen the space of debate even more). This has probably been a false assumption. We did not find any correlations between chat and writing. A deeper space of debate does not necessarily produce a deeper text. It is very well possible that students see chat and text as two unrelated tasks, or that they choose to communicate via either chat or text and don't see the need to use both. Research on multiple representations shows that every representation has its own affordances and constraints, and will be used for different (sub)tasks (e.g., Ainsworth, Bibby & Wood, 2002; Grawemeyer & Cox, 2005). For future research, we would like to have students discuss and use representations without having to write a collaborative text. This way they might be focused on co-construction during chat instead of being focused on finishing the writing-task. Every task activity has to be meaningful to students. It appears that a task that is supposed to support another task is not meaningful in itself for students.

Collaborative argumentation-based learning with diagrams

Argumentative effort in chat and writing leads to broadening and deepening the space of debate. External representations such as a diagram support exploration of the space of debate by providing a basis to talk about, a way to focus on differences between partners, or an information source to tell from.

It is not the case that a diagram supports broadening, while a text supports deepening of the space of debate, and a given diagram support both. Rather, the diagram showed the best results in both broadening and deepening the space of debate. Broadening and deepening are not separate activities (at least not for the students); they both contribute to elaboration of the space of debate.

Our study suggests that a given diagram is not useful for learning. The translation from the textual representation to the diagrammatic representation is made for the students, while our results imply that the *construction* of the diagram is important to support learning. This is much more in line with constructivist theories, in which people learn by actively constructing knowledge instead of passively acquiring it (e.g., Bruner, 1990, Von Glaserfeld, 1989). Another explanation is that the given diagram distracts students. This is not very likely, however, because students did not mention the fact that they had received such a given diagram. We suggest that a given diagram (either generated by a person or computer program) may only be helpful for learning when students have to actively engage with them, and can claim their authorship.

Close inspection of how students used the diagram when exploring the space of debate showed that students do not go beyond the local level of diagram-inspection much. Students explore only to a certain extent. The advantage of a diagram over a text or a given diagram was mostly found in the amount of arguments and the amount of examples and explanations given. This means that the diagram deepened only in a 'shallow' way, with arguments and examples (the first and second category of depth), but not with counterarguments, rebuttals, or explicit relations (the third and fourth layer of depth). It appears that almost all students fail to look at the diagram in a global way, that is, they do not benefit from its overall structure. There are relations in a diagram of course, as there are in text, but we do not see arrows that specifically relate different subtopics or arguments to weigh these. Those explicit relations are necessary to get a grip on the space of debate and to reach conclusions. Instead, students discussed or wrote about each part of the diagram (or text) separately. More research is needed into students' ability and motivation to pay attention to structure and relations in diagrams. They need to be made aware of the possibilities a diagram has. The positive effects we found for the diagram suggest that it can be a better tool for CABLE than the text or the given diagram, but the differences we found in strategies suggest that these effects could be much higher.

Our results imply that representational guidance (whether constructed or inspected) is not a matter of 'plug and play'. Using a representation in CABLE does not automatically lead to broadening and deepening the space of debate, because dyads work very differently with the representations. Representations are used to put information directly from representations to collaborative text, to compare viewpoints and arguments, or to transform the information from the representations into collaborative knowledge during discussion.

For research this means that frequencies don't tell us everything about when and how to use diagrams for CABLE. Much more subtle processes, such as dyads' usage of diagrams, contribute to the results students can obtain. Research into tool support should therefore address not only effects, but also processes of tool use.

For school practice, our results give rise to the question of how to get students to change strategies. Is it possible to help students make optimal use of the tools? One possible solution is to restrict tool and task in such a way that only certain strategies are supported. However, a tool and task that can be employed to support different strategies, topics, and levels of expertise best supports argumentation-based learning in different situations and for different students. This greatly improves usability in schools. Another idea is to put more emphasis on reflection. After using the tool, students can be asked to look back at their collaboration and tool use, and comment on it. This might enhance students' insight in the affordances of the tool. The teacher then plays a very important role in guiding student's collaborative argumentation-based learning with tools.

At the moment, dyads explore the topic only to a certain extent. They sometimes seem to use the available tools as if they try to paste pieces together with a hammer. When they start using their tools in a more effective way, they could make a beautiful knowledge-artefact together.

Appendix A: Diagram made by the researcher from student's text

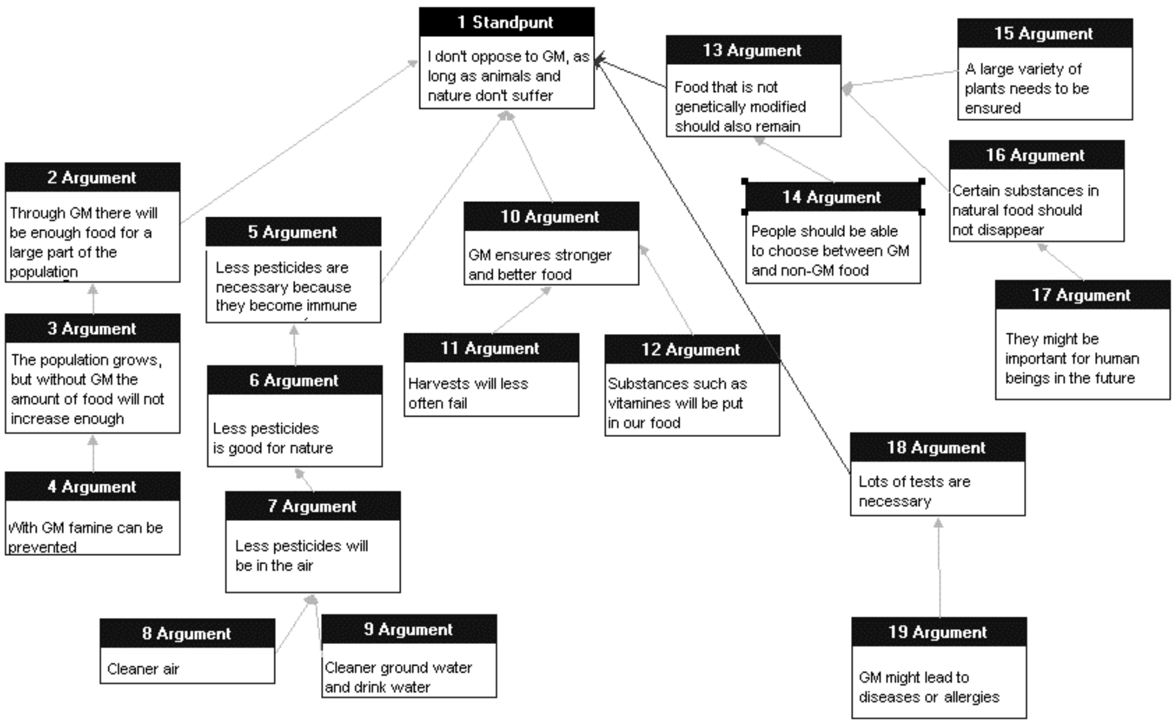
I don't oppose to genetic modification of food, as long as animals do not suffer from it, and nature won't be damaged.

By genetically modifying food there can be enough food for a large part of the population. The population continues to grow but without genetic modification the amount of food will not increase enough. Thus, there won't be enough food in the long run and there will be famine.
Genetic modification will also ensure stronger and better food. Harvests will less often fail and there will sometimes also be other substances (mostly with a positive influence) in the food, such as more or other vitamins.

However, food that is not genetically modified should also remain to exist, in order for people to be able to choose what kind of food they want, and to ensure that certain substances that are not present in genetically modified food, but are present in natural food, will not disappear. Because they might be important for human beings in the future.
It is also important that certain kinds of plants will not disappear at all, because a large variety of plants need to be ensured.

If it is true that fewer pesticides are necessary because of genetic manipulation, because they have become immune, then this is better for nature and that is a large plus. Less chemical substances will be in the air, and this ensures a cleaner air, and thus also cleaner ground water and drink water.

I do think that good tests with the food need to be done first to see whether it is harmful, whether it cannot lead to allergies or diseases.



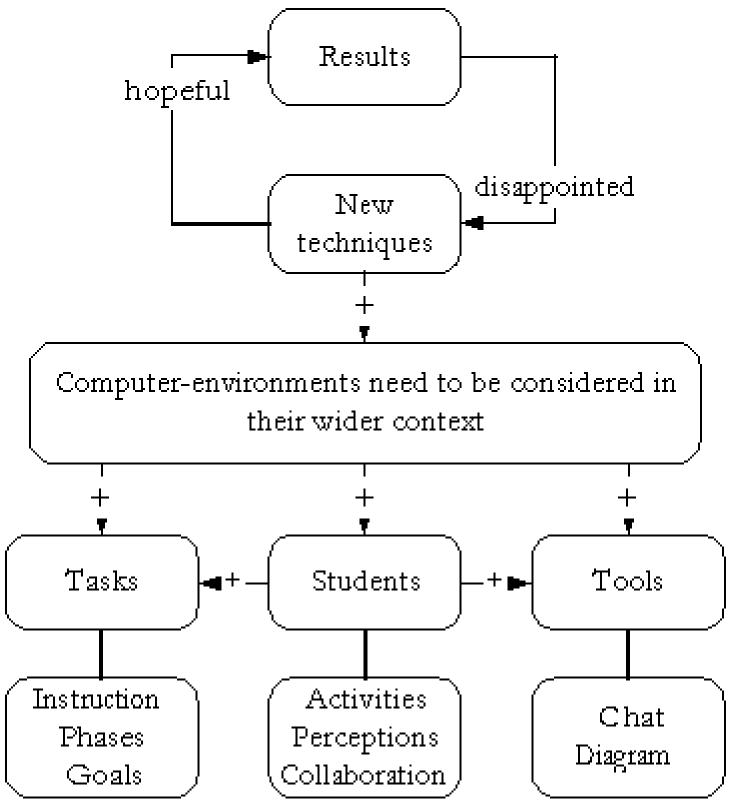
Appendix B: Broadening and Deepening scores

Condition	Dyad	Type	Representation before		Chat		Text		Representation after	
			depth	*breadth*	*depth*	*breadth*	*depth*	*breadth*	*depth*	*breadth*
Diagram	1	1	18.5	5.0	73	9	43	9	21.0	5.5
	2	1	22.0	4.5	103	13	40	7	23.5	5.0
	3	3	13.5	4.5	39	7	48	11	23.0	6.5
	4	2	32.5	9.0	4	7	73	11	33.0	9.0
	5	3	32.0	8.5	29	5	60	11	33.5	9.5
	6	3	30.5	8.0	36	8	57	8	35.0	8.0
	7	1	26.0	7.5	96	12	65	11	31.5	8.5
	8	3	23.0	6.5	37	8	62	9	31.0	7.5
	9	5	15.5	7.0	14	10	52	9	22.0	8.0
	10	3	5.5	3.5	48	9	51	9	17.5	8.5
Text	11	4	44.5	7.0	32	9	27	6	46.0	7.5
	12	2	24.5	6.5	5	5	25	6	32.5	7.5
	13	2	26.0	5.5	4	3	38	9	32.5	7.5
	14	1	29.0	8.0	81	9	56	5	32.0	10.0
	15	1	32.5	7.5	51	11	35	7	42.5	8.5
	16	3	36.5	8.5	39	8	41	10	39.5	8.5
	17	3	29.5	7.5	59	8	51	11	37.0	8.5
	18	1	16.5	6.0	75	9	30	7	17.0	6.0
	19	3	22.5	6.0	28	10	31	9	23.0	6.5
	20	5	23.5	4.5	48	6	38	6	25.5	5.0
Given diagram	21	2	24.5	5.5	14	5	47	6	29.0	6.0
	22	5	22.5	4.5	49	7	45	8	23.5	5.5
	23	2	28.0	6.0	0	1	46	11	28.5	7.0
	24	3	21.0	6.5	22	6	63	8	30.5	8.5
	25	2	9.5	2.0	3	3	48	11	9.5	2.0
	26	1	25.5	5.0	45	9	12	7	32.0	6.0
	27	1	27.0	5.5	48	8	30	6	29.5	7.0
	28	3	18.0	5.0	31	6	38	10	21.5	6.0
	29	5	20.0	4.0	71	7	33	7	22.5	4.5
	30	1	21.0	4.0	54	9	18	5	22.0	4.5

Note. Type: 1 = mountains; 2 = valleys; 3 = rising slopes; 4 and 5 = other types not taken into account for analyses.

4

Tools are not enough:
Learning activities in computer-based discussions



Introduction

It could be argued that language-based communication and tool use are two important developments that have brought mankind to where we are today. Recently computer-based education has combined both developments, providing a promising platform for learning. In the field of computer-supported collaborative learning, a number of beautiful environments have been developed, such as *Belvédère* (Paolucci, Suthers & Weiner, 1995) and *Knowledge Forum* (Scardamalia, 2003). However, the mere combination of language and tools does not automatically produce learning in users. Other factors in an environment can influence the learning experience, such as the nature of the task and the social relation with collaborating peers. Technological innovations must be matched by good implementation of these innovations. In this article, we focus on two factors. We argue that more attention is needed on (i) developing pedagogical strategies in which computer-based environments have added value, and (ii) on the learners who work with these environments. A simultaneous focus on pedagogical design and students' activities within that design can show how computer-based tools may support students in learning from discussing a topic together.

The general context of this research is Collaborative Argumentation-Based LEarning (CABLE) with computer-based tools. Below, we first discuss possible learning activities in CABLE. Then we show how these activities can be supported with computer-based tools and tasks. We identify several issues regarding pedagogical design and computer-based tools that are still unclear. Two studies are described to clarify these issues.

Collaborative argumentation-based learning

Argumentation-based learning can be seen as a special form of collaborative learning. Dillenbourg (1999) described collaborative learning as "a situation in which two or more people work together on a joint goal". In argumentation-based learning, the collaborative work is done by means of argument. The joint goal is to construct knowledge about the topic under discussion. Learning is now widely viewed as a constructive activity in which learners create their own knowledge, based on prior knowledge and new experiences. The focus of this article is therefore on how students construct meaning together by means of argument.

Argument or discussion is beneficial for learning, because it involves reasoning instead of only retrieving information from memory (Andriessen, Baker & Suthers, 2003). Hearing other points of view broadens learners' view on the topic. Reacting to the ideas of others involves looking at the topic from different sides, and for causes and relations to defend or attack (Andriessen & Veerman, 1999). Explaining your own ideas to another person is related to the self-explanation effect (Chi, Bassok, Lewis, Reimann & Glaser, 1989). CABLE may thus be a means to co-construct knowledge, and lead to attitude change or conceptual change (Baker, 1999).

Our pedagogical aim is for secondary school students to explore the 'space of debate' on open-ended issues through argumentative discussion with peers. The space of debate comprises all views, arguments, decisions, facts, emotions, and consequences within an issue. Most people only have knowledge of part of a space of debate. By means of argument they can get a broader and deeper view of the topic under discussion. A broader view of the topic entails more knowledge of subtopics. For example, learners realise that in a debate on genetically modified food they should consider not only environmental factors, but also health factors. A deeper view of a topic entails an elaboration on arguments. For example, learners do not only understand that environmental factors are involved in the issue, but can also explain why this is the case.

We propose that peer talk characterised by argumentative moves (such as arguments, counterarguments, and examples) contributes to learning about the space of debate. Three kinds of knowledge-actions can be distinguished (the words between brackets are used in later analyses). First, an argumentative move can contain new information not previously mentioned in the discussion (*constitute*). Second, it can contain information that is repeated literally (*tell*). Although repetition of information may not seem to add to learning, it could mean that the learner making that move is emphasising its importance, which makes the argument more memorable. Third, an argumentative move can transform previously mentioned information (*transform*), for example by summarising, elaborating, integrating, or combining this information (Vermunt, 1992).

Computer support

A computer-environment provides various tools that have different assets for learning, such as chat and diagram. Learners communicate via the computer in chat. Advantages of chat interaction over face-to-face interaction are that social factors such as status are less evident (Tan, Wei, Watson & Walzuch, 1998), and that the communication is slow, allowing learners to re-read and reflect on information (Veerman, 2000). Compared to interaction via email or discussion forums, utterances are mostly short and turn taking is quick. Additionally, the computer can combine the advantages of reading and writing. Through means of a conversation history learners can read what they have discussed so far. Writing seems effective for learning, because it helps learners structure their thinking process (Rijlaarsdam & Couzijn, 2000; Bangert-Drowns, Hurley & Wilkinson 2004) and generate new ideas (Galbraith, 1992).

An argumentative diagram consists of boxes with arguments, and arrows that relate these boxes with a positive or negative sign (Figure 1). It can be used to communicate argumentation (e.g., Suthers, 2001; Kanselaar et al., 2002) and to structure argumentation (e.g., Schwarz, Neuman, Gil & Ilya, 2000). The communicative aspect is mostly related to the content of the boxes, whereas the structure aspect is related to the two-dimensional space of the diagram.

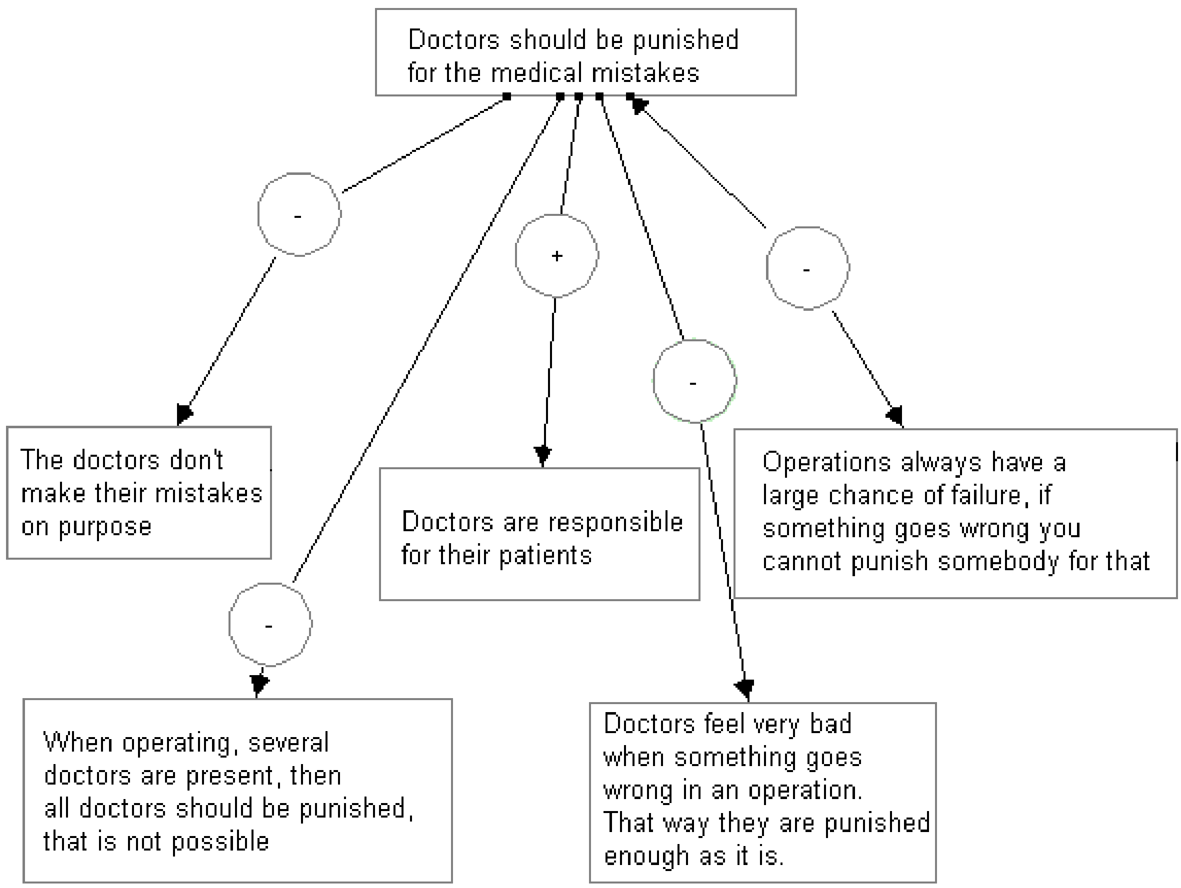


Figure 1. *Example of an argumentative diagram*

Conditions for CABLE to occur

CABLE needs to be embedded in a pedagogical task for learning to occur. Much research has been carried out to determine general task characteristics beneficial for collaborative and argumentation-based learning. For example, Johnson and Johnson (1992) found that it is very important for collaborating learners to have shared goals because this enhances positive interdependency. Participants also need equal opportunities to participate in the discourse (Johnson & Johnson, 1992).

For argumentation to occur in collaborative tasks, the topic should be debatable, there should be a difference in opinion, and a desire to solve this difference through reasoning (Andriessen & Veerman, 1999; Golder & Pouit, 1999; Quignard & Baker, 1999). Cohen (1994) suggested that open tasks, in which multiple possible solutions exist, suit collaborative learning better than closed tasks with one right answer. There should be room for discussion.

On a more specific level, the conditions for learning are not so clear anymore. For example, Veerman (2000) suggested that competitive instructions and predefined conflicting standpoints are useful to provoke argument. In her study, students who received competitive instruction produced 30% more arguments than students aimed at reaching consensus. However, Baker (1999) argues that clearly defined standpoints and a rigid point of view can also be an epistemological obstacle for eliciting cognitive processes. Debate is said to reduce cognitive outcomes, because people get defensive (Johnson & Johnson, 1995). However, it may also enhance motivation, and lead to more argument (Veerman, 2000).

Available tools

Results of research into pedagogical design on collaborative learning without computer-based tools cannot simply be transferred across situations, because a tool inherently changes the task (Lund, Molinari, Séjourné & Baker, 2006). Four issues can be considered with respect to the role of tools in a collaborative learning task: (1) the nature of the tool, (2) whether the tool is used to construct or inspect, (3) the goal for which the tool is used, and (4) the relation between different tools. We will discuss these aspects in light of our own studies.

First, the way information is represented (e.g., in words or in pictures) influences learners' talk about that information. For example, diagrams may focus discussion more on the structure of the argument than chat. Tools can be deliberately chosen to elicit a desired outcome. Van Drie (2005) studied the effects of different forms of representations on historical reasoning. She found that students talked more about historical changes when they constructed a matrix with headings than when they constructed an argumentative diagram.

Second, we need to distinguish inspection of representations from construction of representations. Research has often focused on diagrams, graphs, or models that were made by experts for inspection by learners to help students understand a certain problem (e.g., Lowe, 2004; De Jong & Van Joolingen, 1998). In contrast, a diagram used in CABLE needs to be constructed by the learners themselves. It can help them think about the structure of the argument: what to put in the diagram and where to put it. It can also help them keep a focus on the discussion. During and after construction these diagrams are also inspected, which can help learners see on what points they agree and disagree, see what they have discussed so far, and what further discussion is needed (previous chapter).

Third, the goal for which a tool is used will influence learners' activities. For instance, an argumentative diagram will evoke other activities when learners are asked to make an overview of discussion than when they are asked to generate as many ideas as possible. Different task goals will also elicit different kinds of interaction. A task that is aimed at finding as many arguments as possible elicits enumerating arguments, while a task aimed at reaching a conclusion elicits weighing of arguments.

Fourth, the representations in an environment do not operate on their own. A lot of research has been carried out on multiple representations (e.g., Ainsworth, 1999; De Jong et al., 1998). One of the key components for learning from multiple representations is the translation from one representation to another, such as summarisation from chat to diagram (Ainsworth, Bibby & Wood, 2002). Another key component is splitting tasks to the most appropriate representation, such as using chat to manage the task at hand, and using a diagram to put arguments in. It is feasible that translation issues are especially important when students are asked to chat first and construct a diagram later, and that splitting tasks is seen more when students are asked to chat and construct a diagram concurrently. Therefore, we cannot look at the chat or diagram in isolation.

Design of our studies with research questions

Three points emerge from the discussion above. First, it is unclear whether students should receive predefined standpoints and competitive instructions or be able to have their own viewpoint and explore the space of debate together. Second, it is unclear how computer-based tools should be embedded in the task. We have discussed four issues related to the tools: the nature of the tool, construction versus inspection, goals, and relation between tools. Third, it is unclear how students make meaning together when they work with the tools in a specific situation.

Two studies were carried out to clarify these issues. The research questions are aimed at how students use chat and diagram in different pedagogical designs. In the first study, we wanted to know what activities are carried out in chat and diagram when students (1) elaborated one point of view together, or (2) debate opposing views, using chat and diagram concurrently. Students were asked to elaborate one viewpoint if they agreed on the topic, or try to win the debate if they disagreed. Elaboration is described here as collaborating to explore one viewpoint. This does not mean there is no discussion. There should be discussion to decide what arguments are important, and how to defend from attack. Elaboration is more cooperative, while debate is more competitive. From literature, it is not clear which of the two would lead to the broadest and deepest discussion. We also wanted to know (3) whether students showed improvement in argumentative knowledge of a topic, by asking them to individually construct and revise a diagram before and after discussion. When students construct a diagram individually, they can decide what to put in there and how. When they construct a diagram together, they have to negotiate content and structure, or avoid this by dividing tasks. Division instead of negotiation may happen more often in a win-lose debate than in elaborative discussion, because students do not have to agree on content.

In the second study, we also wanted to know what activities are carried out in chat and diagram when students (1) elaborate one point of view together or (2) debate opposing views. However, this time the two ‘conditions’ were carried out consecutively; dyads first elaborated one given point of view together and then formed different dyads to debate opposing views. This time, the elaboration could be used as input for subsequent debate, possibly giving students a clearer goal for discussion. Moreover, we wanted to know what activities were carried out in chat and diagram if students (3) used chat and diagram concurrently, or (4) used chat to debate, and diagram afterwards to reflect. Constructing a diagram concurrently with or after chat may influence how the diagram is used: as communication medium or as representation of argumentative structure. Concurrent use of chat and diagram was done in the elaboration phase (1), and consecutive use in the debate phase (2). Therefore, we do not have clear comparable conditions, but we can sketch a broad image of how tasks and tools influence collaborative learning. Students also (5) constructed and revised diagrams individually before and after discussion. More detailed information of the two studies will be given in the narrative below.

The research questions are investigated at the level of dialogical activities. We first look at activities in chat and diagram separately. In a microanalysis done on eight students, we also analyse the flow of activities in chat and diagram. In the previous chapter, we found much variety in how dyads carry out their tasks. In this chapter we go deeper into qualitative analyses in which the flow of discussion in chat and diagram is followed closely. This is possible because we use the same level of description for both representations.

Study 1

Method

Participants

The first study was done in an upper secondary school in the Netherlands. Twenty-seven students between 16 and 17 years of age participated. They worked individually and in dyads. Students who missed one or more lessons were excluded from the analyses, leaving 18 students in 9 dyads (3 both female, 6 mixed gender).

Learning environment

Students performed an argumentation-based learning task using DREW, the environment that was developed within the SCALE project (Corbel et al., 2002). DREW is a groupware program that enables students to interact while working at their own computer. Pairs of students communicate via chat and jointly construct an argumentative diagram. Figure 2 shows the shared DREW screen with the chat window on the left and the diagram window on the right. In the top left, students type their chat message. Below, the chat history is shown. In the diagram window students can create boxes and draw arrows between boxes. Every box can be filled with text. Additional pop-up windows (grey box in Figure 2) are available to add comments to the boxes or the arrows. Students can indicate whether they agree or disagree with the content of every box. If the students have the same opinion, two coloured lines are shown around the box. If they disagree, the box changes into a squeezed shape.

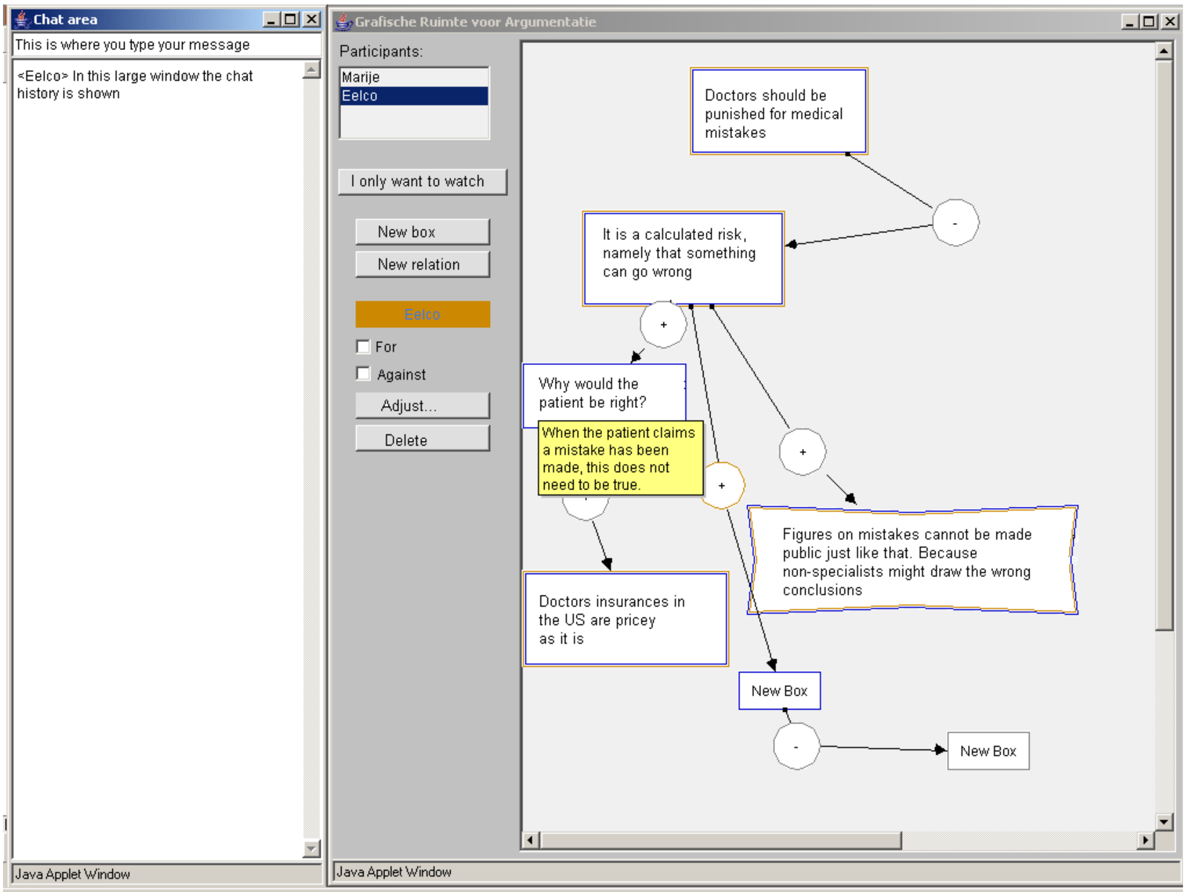


Figure 2. *DREW example (text translated from Dutch original)*

Procedure

The students worked on the argumentation task in five lessons during Biology classes. First, they chose the topic for discussion with the whole class by bringing in ideas and voting on paper (45 minutes). The class decided for 'alcohol and adolescents'. This topic was later refined to the statement: "It is adolescents' own choice to drink alcohol, smoke, or use drugs; the government should not interfere". In the subsequent training phase (60 minutes), students practised with the tool individually, searched for information on the Internet and put this information on the Pedagogical WebSite (PWS, Scale-team, 2003). The information that individuals put on the PWS was accessible to all students. In the preparation phase (20 minutes), students individually constructed a diagram that reflected their own opinion on the statement. In the collaboration phase (60 minutes), students discussed the statement in pairs. Both individual diagrams were available for inspection. When they agreed, they were asked to elaborate upon their point of view in order to convince someone else that their view was right. When they disagreed, they were asked to argue for their own case and try to win the debate. In the consolidation phase (15 minutes), students could change their individual diagrams to give their final opinion and conclusion.

Analyses

Diagram. ADAM (Argumentation Diagram Analysis Method) measures the quality of students' argumentative diagrams by analysing various separate features. It has been developed by our SCALE partners in Lyon in the second year of the project, after Drew was developed (Séjourné, Baker, Lund & Molinari, 2004). ADAM is used in this chapter because all partners in the SCALE project used this method to analyse their diagrams. This made comparison between countries possible. The analysis on broadening and deepening, used in other chapters, is only used in the Netherlands. For this study, we have chosen the ADAM analyses that best measure broadening and deepening the space of debate, namely the form of the diagram (i.e. the number of arrows that derive from the box in which the thesis is put, and the maximum depth of boxes from the thesis), the quantity (number of boxes, number of comments) of arguments, the quality (level of content in boxes and arrows) of arguments, and the topics mentioned (number of topics in boxes and arrows).

Chat. Students' chat was analysed with the Rainbow framework, also developed in the SCALE project. Rainbow categorises the messages the students convey into seven functional categories (see Baker, Andriessen, Lund, Van Amelsvoort & Quignard, 2006, for a detailed discussion of Rainbow). The first category is outside activity, in which students talk about things that are unrelated to the task (e.g., the party they had the other night). The second category, social relation, contains utterances regarding students' relation, such as greetings. The third category, interaction management, contains utterances to handle the communication. Categories four to seven are task-related. Category four is task management; categories five to seven include argumentative interaction on the topic (opinions, arguments, and explore and deepen respectively).

Results study 1

Elaboration versus Debate

In the collaborative phase, students were asked to investigate whether they agreed or not about the statement: "It is adolescents' own choice to drink alcohol, smoke, or use drugs; the government should not interfere". However, it proved to be impossible to distinguish the two kinds of collaboration. When we read through all the chats, five out of nine dyads indicated that they agreed on the statement, but their diagram was not an elaboration of their joint standpoint. Moreover, it was impossible to see which diagram was an elaboration of one standpoint, and which stemmed from a win-lose game. When reading through all protocols, we noticed that especially when students agreed on the standpoint, they seemed not to see the point of discussion or diagram construction. In the remainder of this results section, we will therefore look at the results of all students together.

Diagrams

Students constructed three diagrams in total: one diagram to express their individual opinion before discussion (diagram 1), one collaborative diagram created during discussion in pairs (diagram 2), and one diagram to express their individual opinion after discussion (diagram 3). Table 1 presents the results of the ADAM analysis on the diagrams.

There was a significant difference between the first, the second, and the third diagram for most of the analyses. Students addressed more topics in the collaborative diagram (2) than in the preceding individual diagram (1), constructed a deeper diagram, elaborated their arguments in the titles of the boxes to a deeper extent, constructed a larger number of boxes, and a larger number of comments. The individual diagrams that were revised after discussion (3) were mostly broader and deeper than the first individual diagrams (1), but not broader and deeper than the collaborative diagrams (2).

Students created relations, but did not use the comment boxes to elaborate upon these relations. The students did use the comment boxes to elaborate upon the argument boxes, most of all in the collaborative diagrams.

Table 1. *Means and F-values of space of debate in diagrams for study 1*

ADAM Categories	ADAM Analyses	dia 1 *M*	dia 2 *M*	dia 3 *M*	*F*
breadth	number of arrows from the thesis	2.53	4.33	3.29	2.55
	number of topic addressed in the boxes				
	- same topic counted once	2.76[a]	3.33	3.59[b]	4.07*
	- same topic counted as many times as it occurs	4.65[a]	8.33[c]	6.76[b]	14.43*
	number of topics addressed in the relations	0	0	0	n.a.
depth	maximum depth	1.94[a]	3.33[b]	2.59	4.97*
	the level of content in the boxes				
	- text in boxes	10.41[a]	22.00[c]	16.71[b]	17.77*
	- comments	3.12	3.00	3.12	.01
	the level of content in the relations	0	0	0	n.a.
both	number of boxes	5.76[a]	10.44[c]	8.06[b]	23.80
	number of comments	4.24[a]	8.89[c]	6.47[b]	11.83

Note. Means in a row with different superscripts differ significantly at the .05 level in post-hoc analyses.

Chat

During the collaborative phase, students did not only create a diagram together (diagram 2), but also used chat to collaborate. Rainbow analysis on the chat (Figure 3) showed that students used chat mostly to manage the task at hand (38%); managing what had to be put in the diagram, by whom, and when. The chat was also used a lot to talk about issues that were not related to the task (outside activity; 18%). Content interaction (opinions, arguments, and explore and deepen together) comprised 18% of all chat interaction. However, the error bars show that the variation between dyads was substantial. For example, the proportion of content interaction ranged from 0% to 72%.

Relation between diagrams and chats

To understand the relation between students' activities in chat and in diagram, correlational analyses were performed. The analyses showed no significant relations between the content related interactions in chat and the number of boxes, number of comments, number of topics, and level of content in the diagram.

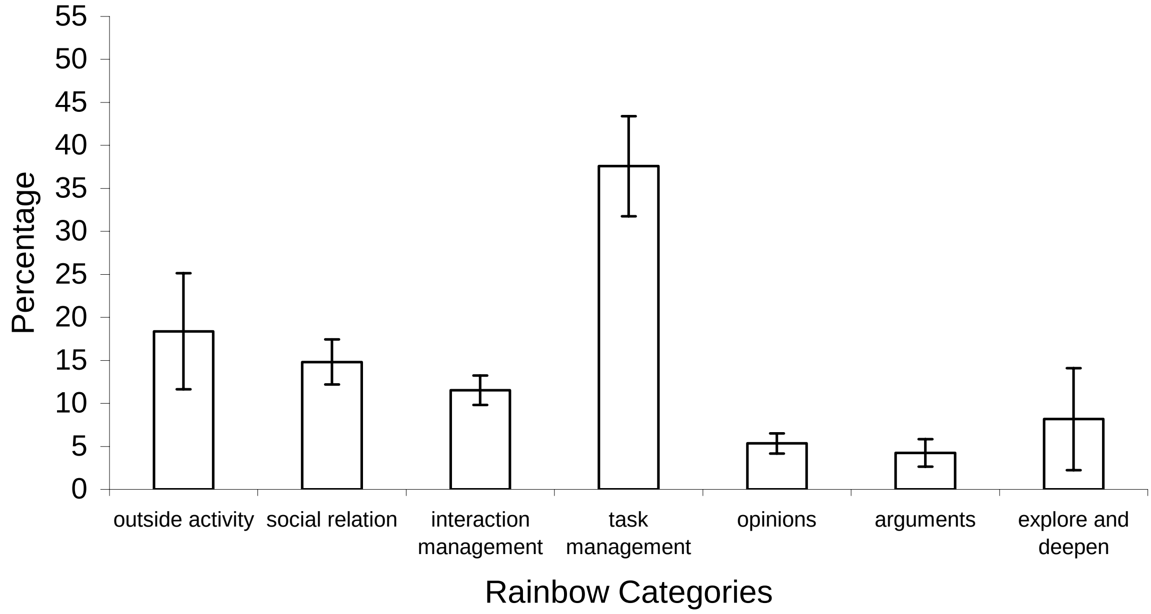


Figure 3. *Rainbow percentages in chat (study 1)*

Discussion first study

Students were given the choice to elaborate one standpoint or to debate two standpoints, but we found that the two could not be distinguished. Our study did therefore not prove one task to be better than the other. It is possible that the choice was too difficult to make for students. They needed to discuss their points of view, probably found that they agreed on some points and not on other points, and therefore could not decide what to do. It is also possible that the task design was flawed. Students did not see the point of a discussion if they both agreed. Apparently, the task did not make sense to the students, because they did not see a clear goal. To eliminate the last possibility, goals are changed in the second study.

Students individually improved their spaces of debate after discussion compared to before discussion. They created more boxes and lines, represented more topics, addressed them more often, and elaborated further upon the titles of the boxes. The collaborative diagram was even better than the individually constructed and revised diagrams. Students broadened and deepened their space of debate considerably during discussion, but they did not convert this all to their revised individual diagrams. While collaborative construction of diagrams involves (further) exploration of the space of debate together, individual revision of diagrams is probably more related to representing the current space of debate. These are two very different activities.

The comment boxes on relations were never used. The comment boxes on boxes were used in the collaborative diagrams, but not in the individual diagrams. Commentary seems to be mostly related to communicate extra information to a partner. In an individual diagram there is no need to explain or expand your own boxes.

The relation between chat and diagram was unclear. We did not find any significant correlations between chat and diagram, either positively (a lot of argumentative content in both chat and diagram) or negatively (a lot of argumentative content in either chat or diagram, but not in both). Thus, students did not translate argumentative content between chat and diagram. Students did split part of the task to the most appropriate modality: outside activities and management activities were only done in chat, and never in the diagram. However, considering the lack of negative correlation between chat and diagram, they did not split all argumentative content in either chat or diagram.

In short, we replicated some findings from the study in chapter 3. First, students improved their space of debate individually. Second, the relation between chat and diagram was unclear, as it was with chat and collaborative text in the previous chapter.

Study 2

In view of the limitations of study 1, we decided to carry out a second study, in which we changed parts of the task. Students first made an individual diagram on an appointed position. Students could indicate their position on a five-point scale, but because the class was not equally divided in for and against, we could not assign everyone's own position. We made a clear distinction between the two kinds of discussion. Students were asked to first work in dyads to elaborate upon one point of view. This was a preparation for the second phase, in which each student had to form a dyad with a student who supported the opposite point of view in order to win the debate. The diagram in the debate had to be made after discussion, displaying who had won the debate and why. This was done to have students focus on their debate in chat first, instead of having them focus on finishing the diagram. We also asked students to change the individual diagram on paper. They were asked not only to change the diagram in the light of the discussion, but also to indicate the importance of each argument and their opinion on the learning experience. This was done to have students reflect on the discussion more. Chat and diagrams were analysed in the same way as in study 1, but we also carried out microanalyses to investigate the relation between chat and diagram further.

Method

Participants, materials, procedure

The second study was done in the same upper secondary school as the first one, in a parallel Biology class. Eighteen students participated (9 female, 9 male). All pairs were of mixed-gender. This class chose the topic of 'medical mistakes' in their first session. This topic was later specified into the thesis: "Doctors who make a medical mistake should be punished". Figure 4 shows the phases of study 2, and indicates how dyads were formed.

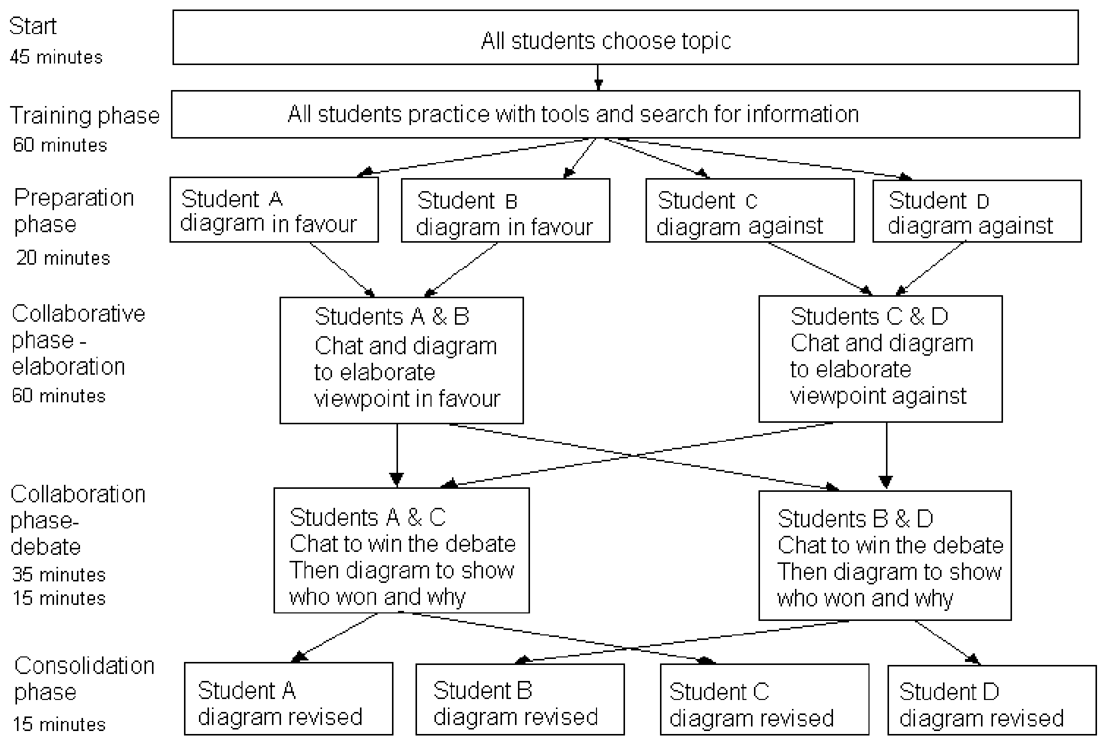


Figure 4. *Task design study 2, illustrated in depth for four students*

Results study 2

Diagrams

Students constructed four diagrams in total, one to express individual opinion before discussion (diagram 1), one collaborative diagram to show elaboration during discussion of one point of view (diagram 2), one collaborative diagram to show the outcome of the win-lose game (diagram 3), and one individual diagram after discussion, to reflect possible change in opinion and learning gains (diagram 4). Table 2 shows the results of ANOVAs done on the ADAM analysis.

The only significant difference between the diagrams is the number of arrows that derives from the thesis. Post-hoc comparisons show that this number is higher for the diagram in which the students elaborate the same point of view (M_{dia2} = 5.7) than for the diagram in which they have a win-lose debate (M_{dia3} = 2.4).

Table 2. *Means and F-values of space of debate in diagrams for study 2*

ADAM categories	ADAM Analyses	dia 1 *M*	dia 2 *M*	dia 3 *M*	dia 4 *M*	*F*
breadth	number of arrows from the thesis	3.44	5.71^{b}	2.38^{a}	3.65	2.55*
	number of topics in the boxes					
	- same topic counted once	3.00	3.43	2.88	2.88	.77
	- same topic counted as many times as it occurs	5.06	6.29	5.50	5.00	.90
	number of topics in the relations	0	0	0	0	n.a.
depth	maximum depth	1.60	1.43	1.63	1.53	.06
	the level of content in the boxes					
	- text in boxes	9.56	17.00	15.25	9.83	3.50
	- comments	7.07	4.29	3.38	7.07	1.22
	the level of content in the relations	0	0	0	0	n.a.
both	number of boxes	6.22	7.43	7.50	7.11	.42
	number of comments	3.33	4.86	6.13	3.33	1.87

Note. Means in a row with different superscripts differ significantly at the .05 level in post-hoc analyses.

In the final individual diagram students did not only change boxes, but were also asked what their opinion was, what they had learned, and what was important. Five students did not express their opinion, five indicated their opinion hadn't changed, two indicated they changed their opinion, and three indicated that their opinion was stronger or weaker than before. Furthermore, three students specifically indicated that they had trouble with the debate, because they had to defend an opinion that was not their own. One student said that she believed that people being against the thesis would always win from the people in favour on this particular topic. Six students indicated they had learned from the task, and used arguments such as 'good for social skills', 'good for expressing yourself', 'good arguments from the opponent'. Five students indicated they had not learned from the task. Some students indicated importance of arguments by numbering the boxes, others by deleting boxes that were not important and circling boxes that were important.

Chat

The Rainbow results of students elaborating the same point of view (the 'elaboration phase') and then trying to win the debate ('debate phase') can be seen in Figure 5. We performed a MANOVA to see the possible differences between the two phases. The multivariate effect was significant, $F(6, 8) = 6.89$, $p < .01$. Univariate analyses showed significant differences for Rainbow categories (5) Opinions, (6) Arguments, and (7) Explore and deepen ($p < .05$), and a marginally significant difference for (1) Outside activity ($p = .05$).

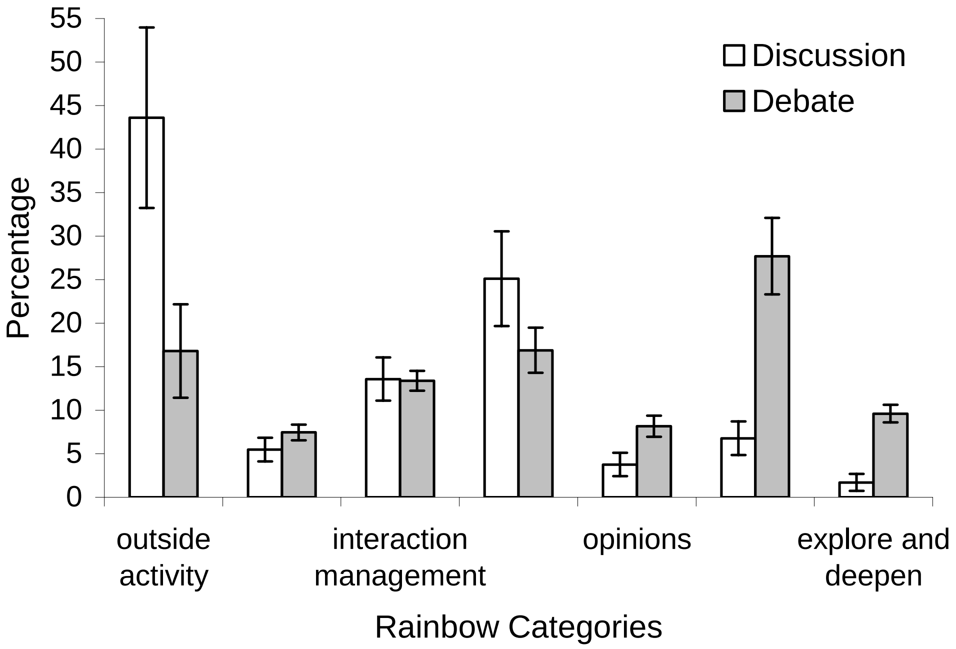


Figure 5. *Rainbow percentages in chat (study 2) during elaboration (left) and debate (right)*

Relation between diagrams and chats

Correlation analyses were performed between chat and the concurrent diagram (diagram 2) in the elaboration phase. One dyad, an outlier, was taken out of the analysis. A positive correlation was only found for the relation between the number of arguments in chat and the number of topics in the diagram ($r = .962$, $p < .01$). A negative correlation was found for the relation between the amount students explored and deepened the chat, and the level of comments in the diagram ($r = -.86$, $p < .05$).

Correlation analyses between chat and consecutive diagram (diagram 3) in the debate phase showed a positive correlation between number of arguments in chat and number of topics in the diagram ($r = .82$, $p < .05$). A negative correlation was found between the number of opinions in chat and the level of comments in the diagram ($r = -.76$, $p < .05$).

Discussion second study

In study 2, the task was artificially divided in a phase where students were asked to collaborate to elaborate one point of view (2) and a phase in which they were asked to debate opposing points of view (3). In the elaboration phase students made a diagram while discussing in chat. In the debate phase students made a diagram after debating to win in chat.

The diagrams made during discussion to elaborate one viewpoint (diagram 2) and after debate on opposite viewpoints (diagram 3) were the same, except for the number of branches from the thesis, which was much higher for the elaboration diagram than for the debate diagram. This indicates that students in the elaboration phase (2) explored the space of debate much more in breadth, looking for different argumentative lines that could back up their argument. The debate diagram, made after debate in chat, is not so wide-branched, giving an overview of the arguments that led to victory (or defeat). Students were asked to collaboratively construct a diagram in the DREW environment twice, which may have accounted for the fact that the diagrams are very similar in other respects.

The chat, in contrast, shows many differences between the elaboration phase (2) and the debate phase (3). The percentage of content related activities (Rainbow categories 5,6 and 7) is much higher (45%) in the debate than in the elaboration chat (14%), while outside activity diminishes (from 35% to 17%). In absolute terms, on average 19.5 moves in students' discussion were argumentative (categories 5,6, and 7) in the elaboration phase, while in the debate phase this increases to 63 moves. Several factors could account for this finding. First, students could have learned how to use the program. They first elaborated one viewpoint, and then debated opposing viewpoints, so they could have learned about the important content-related categories, and don't need outside activity or task-management to get acquainted with the task anymore. Second, the goals of the chat were different in the two tasks. Debating is more an act of defending and attacking with arguments, while elaboration is more an act of exploring the space of debate. We may therefore see an explosion of arguments in the debate phase. Third, chat and diagram were used simultaneously during the elaboration phase, but consecutively in the debate phase. This may mean that part of the discussion in the elaboration phase took place in the diagram instead of the chat. Consequently, there may be less content interaction in chat. Also, less task management was necessary when debating, because the diagram does not have to be created at the same time. The correlations between chat and diagram are inconclusive on this point. The only positive relation between the number of arguments in the chat and the number of topics in the diagram suggests that students put arguments they have discussed in chat also in the diagram. We expected this for the debate phase, in which students have to give an overview of their chat in their diagram, but it also happens in the elaboration phase, where we expected a complementary use of chat and diagram. The negative correlation (in the elaboration phase) between Explore and Deepen in chat and the level of comments in the diagram suggests this complementary use of the diagram. Apparently, students who elaborate towards the same point of view put their argumentative chat in the diagram, but only on a surface level.

Comparison first and second study

The second study was designed to give students a clearer goal for elaboration and debate, to distinguish between separate and concurrent use of the diagram, and to have students reflect on their collaboration more. A synergistic look at the data suggests that students knew better what was expected of them in the second study compared to the first. However, the results did not show improvement in broadening and deepening the space of debate with the 'improved' pedagogical design of study 2.

The individual diagrams constructed at the start of the task do not show differences, except in level of comments of the boxes $t(22) = 2.29$, $p < .05$. This indicates that it does not matter whether students have to indicate their own opinion or to present an imposed opinion when constructing a diagram. There are more differences between the revised individual diagrams after collaboration, which may indicate an effect of either the collaborative phases, or may be related to the difference between the two studies in revising the individual diagram.

In summary, we found some evidence that different activities and goals do make a difference in how students work at the task. However, we also found a lot of variance between dyads. This indicates that task differences alone do not account for results. Moreover, we want to understand how two students execute the task at hand using chat and diagram in combination. The analyses done so far did not provide conclusive results. Therefore, we performed a microanalysis on eight students in four dyads.

Microanalysis 8 students in 4 dyads

A microanalysis was done on eight students from study 2 (four students started with being in favour and four against the thesis on medical mistakes). We followed the students individually and in dyads, investigating all content-related interaction in diagrams and chat. Then we analysed the flow of arguments throughout the task, relating what was done in the diagrams with what was done in chat. For example, we checked whether an argument a student mentioned in the elaboration phase was already present in her individual diagram, and if so, in what form. Inspired by similar notions from Bereiter and Scardamalia (1987) and Galbraith (1992), we distinguished three kinds of knowledge-actions, mentioned in the introduction. If a concept or argument was already present in a previous representation in the same form, students were said to be *telling* arguments. If it was already present, but students changed it, they had *transformed* the concept or argument. If it was new, students had *constituted* new information or knowledge. When students transformed knowledge, we specified what they changed, for example, whether it was elaborated upon, summarised or specified. Table 3 displays an example of part of an analysis.

Table 3. *Example of microanalysis*

Modality	Dyad	Content	From	TCT	Specification
dia	Tijn	Doctors who make mistakes should be punished	assignment	tell	
chat	Loes	Making mistakes is human	own diagram	tell	
dia	Loes	Making mistakes is human	own diagram and chat	tell	
dia	Loes	Relation between box 1 and box 2 with '-'	own diagram	tell	
…					
dia	Tijn	There is always a risk that something goes wrong	own diagram	transform	specify

Note. TCT stands for tell, constitute, transform.

The microanalysis confirms the findings of the previous analyses, in that we saw that all students worked very differently at the task. More importantly however, we found three dimensions that seem to be crucial in the development of arguments and concepts used in chat and diagram. Good and bad dyads (i.e., dyads who explore arguments and concepts to a far extent versus dyads who don't do that) could be distinguished on three dimensions:

The extent to which

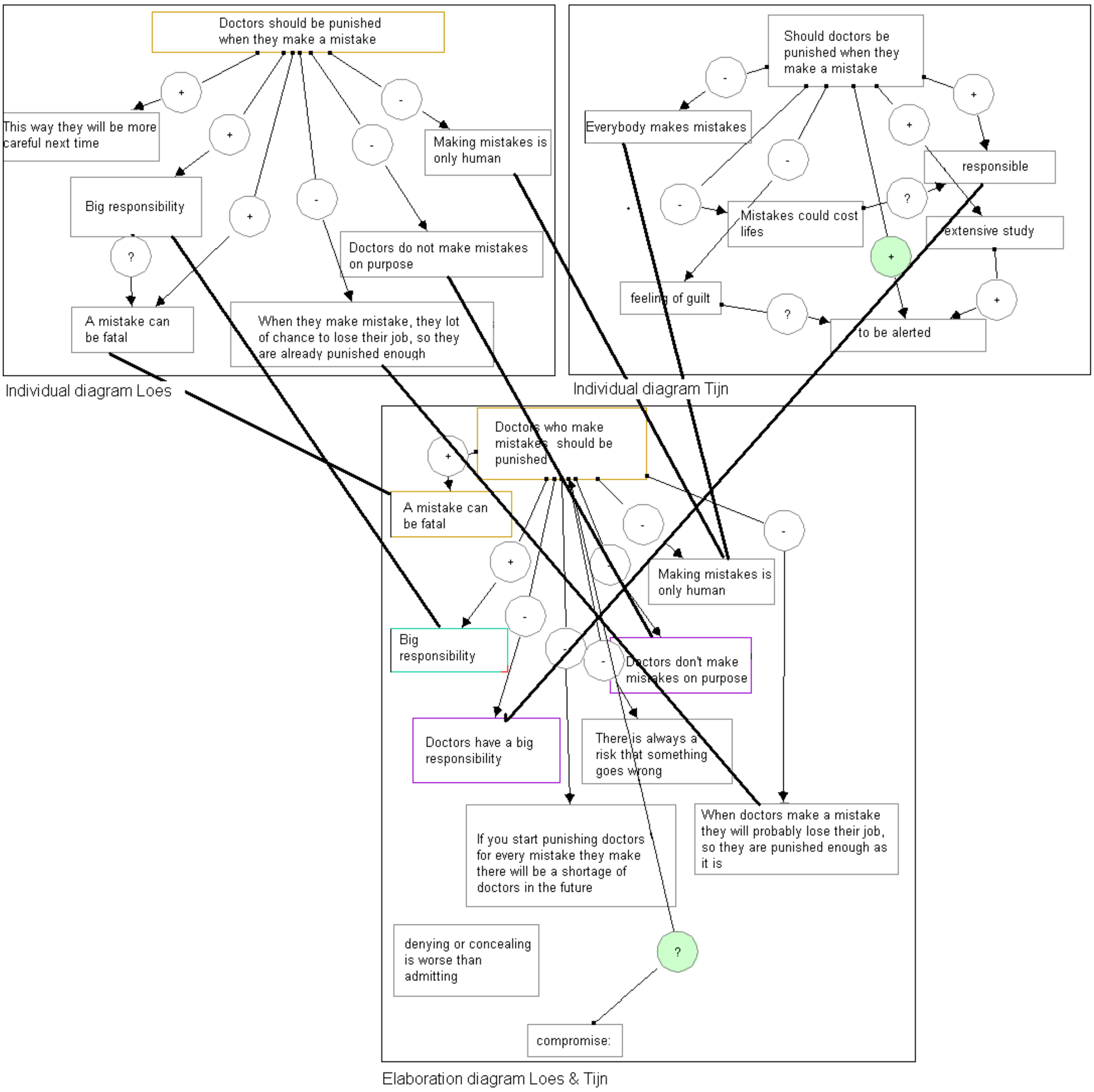
(i) diagrams function as input for activities in the subsequent phase
(ii) students effectively collaborate to transform knowledge
(iii) students have difficulties translating between chat and diagram

We therefore argue that diagrams can be useful for CABLE, but only if learners collaborate seriously, and (learn how to) use the diagrams in an optimal way. The dimensions are discussed in detail below, showing examples of chats and diagrams to back up our argument.

(i) *The extent to which diagrams function as input for activities in the next phase*

In every phase but the first, diagrams from the previous phase are available. Diagrams are thus constructed in one phase and inspected in the subsequent phase. We found that all students use their constructed diagrams as input for the next phase, but differ in how they do that (see also Chapter 3). Some dyads use the diagrams to copy boxes directly to their new diagram, others use them as input for discussion.

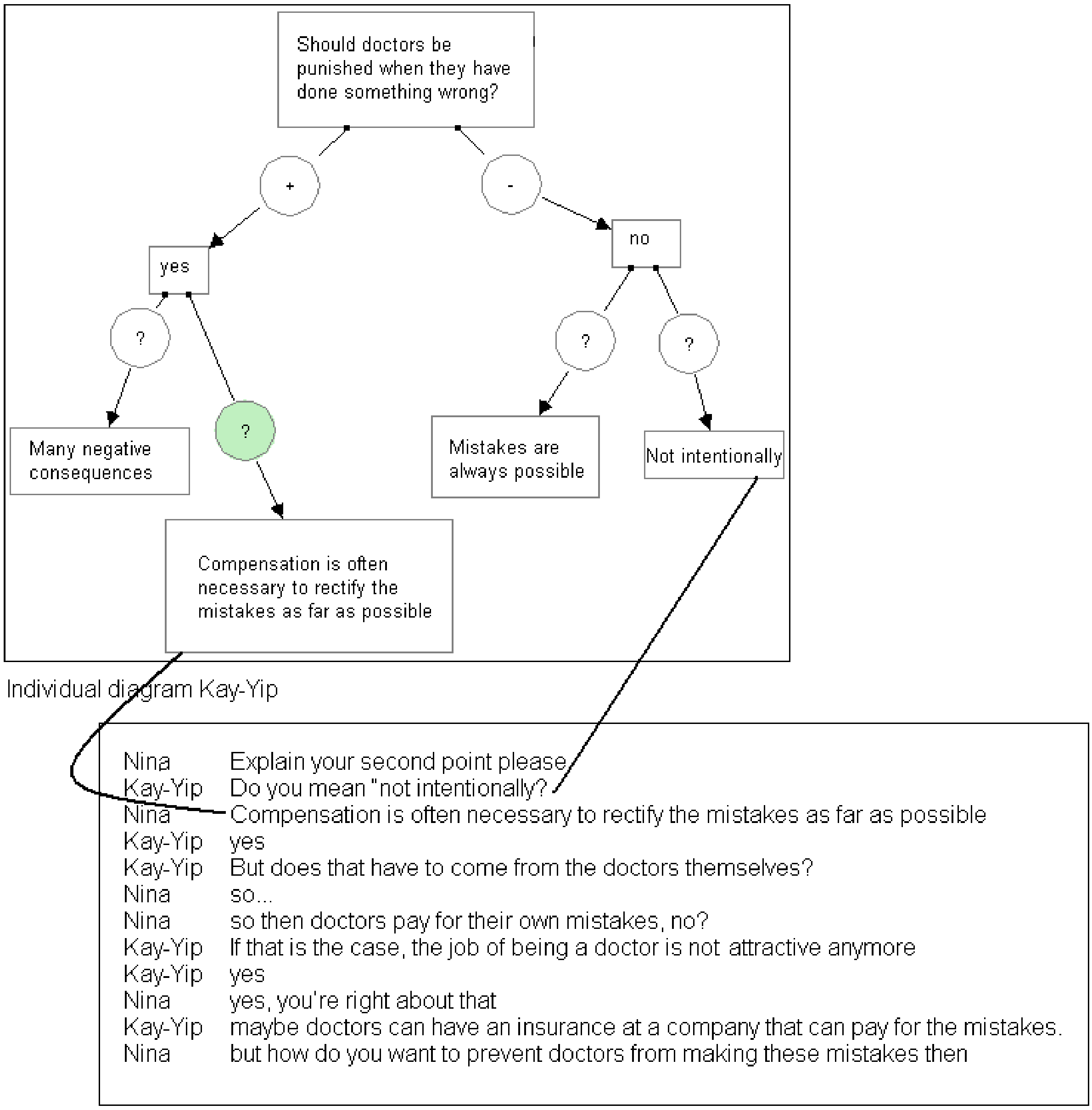
Tijn and Loes for example (Figure 6), only mentioned one argument in chat, the rest of the chat consisted of non-content related utterances (categories 1 to 4 in Rainbow). All arguments were directly put from their old diagrams into their new diagram, albeit sometimes in other words. There seemed to be a sense of 'ownership' of arguments; students only put arguments in the new diagram that stemmed from their own diagram. In these eight students we followed, students used their own arguments in 79% of all cases, and only used other's arguments in 6% of all cases (the other 15% were arguments from both students).



Note. Thick lines added by the researcher to indicate relations between diagrams.

Figure 6. *Individual diagrams copied to collaborative diagrams*

Nina and Kay-Yip, on the other hand, discussed a lot in chat and used input from their individual diagrams to elaborate upon them. They also related arguments from their separate diagrams. In Figure 7 an excerpt of their chat is shown, in which an argument of Kay-Yip's individual diagram was discussed.



Note. Thick lines added by the researcher to indicate relations between diagram and chat.

Figure 7. *Individual diagram leads to elaborated discussion*

(ii) *The extent to which students collaborate effectively to transform knowledge*

The second finding relates to how students work together. As we have already seen above, dyads show different strategies in handling the task. Tijn and Loes for example put their individual diagrams directly in the diagram they were creating together, without talking about them. Most arguments ended up in the new diagram in exactly the same form as in the individual diagrams. Students were both working in their own building blocks of the diagram, and did not relate these in chat, nor in diagram.

The students who did collaborate, either by talking in chat or by relating boxes in the diagram, transformed their knowledge. For example, Max and Loes collaborated in chat by discussing their arguments (Table 4).

Table 4. *Collaboration in chat leads to transformation of knowledge*

Name	Chat	Activity
Loes	They will be more careful next time	Tell from own diagram
Max	They won't be more careful, they won't even start	Transform: combining both diagrams
Max	Because who wants to take the risk of being punished when making a mistake	Tell from own diagram
Max	Mistakes are only human	Tell from both diagrams
Max	And because doctors are also human	Constitute new argument
Max	That can happen, because it is not their intention to make mistakes, I don't know whether you think that it is	Transform own diagram to explain
Loes	Yes, but if they don't start, then there won't be any doctors left?	Transform: combine chat and own diagram
Max	Indeed, so you shouldn't punish doctors when they make a mistake	Transform: conclusion from chat

Effective collaboration is mostly seen in chat, not in diagrams. Students often put arguments in the diagram individually, without reacting on each other's boxes. Consequently, the diagram does not contain a lot of elaborated knowledge, but knowledge that was present in the individual diagrams or in chat. In the next example (Table 5) we see an elaboration of a concept in a diagram, where Tijn commented on his own box. This elaboration is not a collaborative activity. The two students possibly did not even read each other's arguments, since Loes created a box ('big responsibility') that Tijn already created before ('Doctors have a big responsibility').

Table 5. *Diagram is not a collaborative construction*

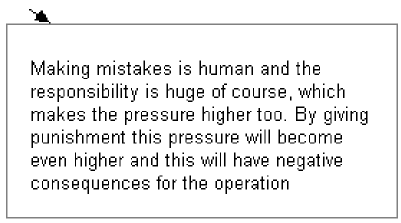
Name	Diagram	Activity
Tijn	Doctors who make mistakes should be punished	Tell (assignment)
Loes	Making mistakes is only human	Tell from own diagram and chat
Tijn	Doctors have a big responsibility	Tell from own diagram and chat
Loes	Doctors don't make mistakes on purpose	Tell from own diagram
Loes	A mistake can be fatal	Tell from own diagram
Tijn	There is always a risk of something going wrong	Specification of own diagram 'everybody makes mistakes'
Tijn	Comment: nobody is perfect. The patient chooses the operation and has to acknowledge the risks	Elaborate own diagram 'doctors are also human and they are thus not perfect'
Loes	Big responsibility	Tell from own diagram

(iii) *The extent to which students have difficulties translating between chat and diagram*

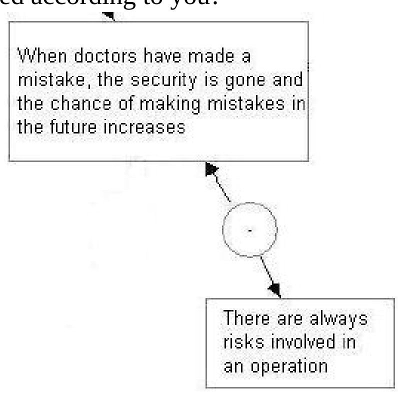
So far, we have mostly been talking about diagrams made in a previous phase for use in a subsequent phase (inspection of diagrams). Students used these diagrams as input for their discussion, either by copying the information literally, or by transforming the information to arrive at changed concepts or arguments.

When dyads construct a diagram, they seem to have difficulties translating between chat and diagram. For example, Gijs and Nina beautifully refined their ideas in chat (transformation and constitution of knowledge). However, when they started to construct the diagram, they resorted to copying boxes from their previous diagram. They talked in chat about what a mistake is exactly, whether there are different kinds of mistakes, and what kinds of mistakes should be punished (see part in Figure 8). The only two boxes in the diagram about this subtopic were two boxes that were present in Nina's individual diagram in similar form.

	…
Gijs	I don't think so….a mistake can always happen
Nina	but you have mistakes and mistakes, not?
Nina	mistakes because of not paying attention
Gijs	And mistakes, and mistakes
Nina	for example
Nina	This should be punished
Gijs	And also mistakes, + mistakes
Nina	???
Gijs	No, I understand what you mean, but I presume that the mistakes we're talking about are not made because of not paying attention
Nina	because of what then?
Gijs	Just like that, that is the bad thing about such a situation
Gijs	Everyone makes mistakes..and some of them unfortunately have fatal consequences
Nina	For what kind of mistake should a doctor not be punished according to you?
Nina	A real error I mean
Gijs	If you can show that the doctor was not seriously carrying out his profession, which is of course very hard.



In individual diagram Nina



In collaborative diagram Nina & Gijs

Note. Thick lines added by the researcher to indicate relations between diagram and chat.

Figure 8. *Translating between representations is difficult*

The best translation we saw between chat and diagram was in the debate between Lily and Tijn. They debated the number of mistakes that are made every year, and disagreed on whether this is a lot or not. They used arguments from their previous diagrams, leading to transformation of knowledge. In the collaborative diagram they constructed a box that contained the heart of their discussion (3% is too much), and indicated their disagreement by crunching the box. The comment box elaborated upon the argument (Figure 9).

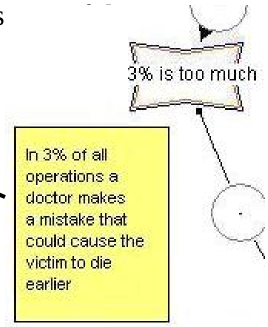
Mistakes can take lives

In diagram Tijn

Everyone can make mistakes, doctors too

In diagram Lily

Lily	Looking at the numbers of patients who survive treatments, the number of mistakes is very small
Tijn	You're wrong there, there are more deaths every year from medical mistakes than from unnecessary traffic victims
Lily	Yes, but how many people are cured in a year, also more than all traffic victims
Lily	and moreover, the standpoint is about whether a doctor should be punished, because I don't agree with that
Tijn	about 3% of the total number of treatments is uns because of a doctor
Lily	doctors can make mistakes, just like everybody, and they have to take risks at times
Lily	97% is thus cured!!!!!!!!!!!!!!1
Lily	that is a lot!!!!
Lily	imagine you get 97% on your math test
Lily	then you'll have a 9,7



In collaborative diagram Tijn & Lily

Note. Thick lines added by the researcher to indicate relations between diagram and chat.

Figure 9. *Example of translation between representations*

General discussion

Tools such as the ones described in this article do not make a difference on their own. The experience has been that "the classroom culture bends such tools to its own interests, and that this culture must be transformed before new media can mediate learning the way we had hoped they would." (Stahl, 2002a). Although we do not want students to rigidly follow a number of pre-defined steps to learn 'a trick', we of course have expectations of what they are to do with our tools. We want them to broaden and deepen understanding of a space of debate, not to chat happily and create a diagram because that is what was asked from them. Some students in our studies did the former, while others did the latter. In general, all students learned from discussing a topic with their peer in the computer-based environment, although not to the extent we envisaged. Learning is subtle (Baker, 2004); old information is often re-told in new combinations, which leads to new relations between information.

Our studies have shown that the pedagogical design around computer-based tools partly determines the extent to which students learn. For example, students engage in a much more argumentation-focused discussion in chat when they are asked to debate to win than when they are asked to elaborate one viewpoint. Learning seems to work best if collaborating students have different opinions, preferably their own, because students with an imposed opinion indicated having difficulty with arguing for a case that was not their own.

More importantly, the huge variety in dyads shows that the way students interact with each other and the tools is even more crucial than the general pedagogical design. One of the key issues here appears to be what we called effective collaboration. When students discussed the topic in length in chat and put shared ideas in the diagram, more transformation of knowledge was seen. Transformation of knowledge is related to learning, because students change, refine or redefine knowledge when transforming.

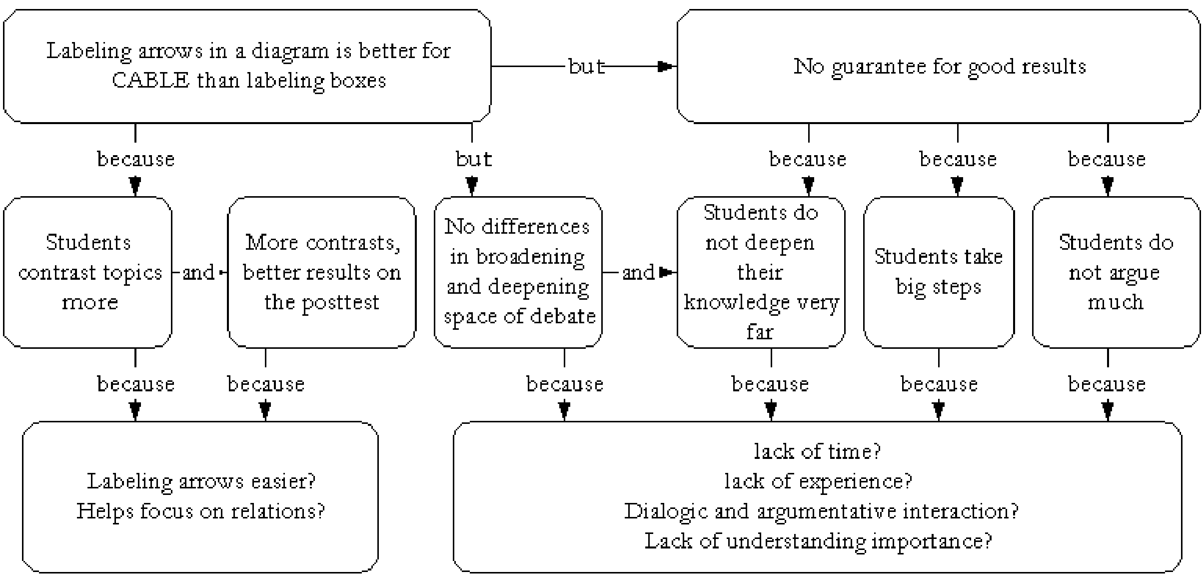
The problematic relation between chat and diagram is another key issue in our findings. Translation between representations can enable students to see complex ideas in a new way (Kaput, 1989). The only positive correlation we found between chat and diagram was between the number of arguments in chat and the number of topics in the diagram. The topics students discuss in chat seem to end up in the diagram. However, in general students used the diagrams for other activities than the chat. Chat had three different functions: to discuss off-task topics, to manage the task at hand, or to have a discussion about the topic. Diagrams only showed content-related arguments. Most students used the two representations to split activities to the most appropriate one, rather than to translate between representations, which makes transformational activities more likely to take place. The same was found in the translation from collaborative to individual phase. Individual students did not translate breadth and depth of the collaboration phase to their individual diagram. It is unclear whether students cannot or do not want to translate between representations, or may not see the benefits of doing so.

CSCL-research tries to show the benefits of using computers while at the same time trying to find out how these tools should be used. The results of our studies suggest that it may be much more important that students learn how to use the tools than that we search for the optimal learning environment with the best learning results. At the moment, the extent to which students collaborate is the most important factor for success in collaborative argumentation-based learning with tools. If students could also learn how to use the representations in their collaboration, they may benefit from computer-supported learning more. Scripting is a possible way of helping students to use chat and diagram in an optimal way (see e.g., Weinberger, Ertl, Fisher & Mandl, 2005).

We have tried to take collaborative knowledge building, mediation by representations, and microanalysis of actions into account (cf. Stahl, 2002b) to paint a bigger picture of what happens when tools are used in schools. Of course, this picture is far from finished. The phenomena found in our case studies need to be investigated further. Detailed analyses like the ones described above (cf. Roschelle, 1992; Chernobilsky & Hmelo-Silver, 2005) can help us find key-features of collaborative learning, so we can research these features over longer periods of time, when they are embedded in the school curriculum.

5

How students structure and relate argumentative knowledge when learning together with diagrams



Introduction

The time of boring course books with lengthy texts is long gone. Nowadays textbooks are covered with pictures and diagrams, and many books are completed with collaborative tasks and simulation environments to have students actively construct their own knowledge. Argumentation-based learning is described as an activity in which two or more people construct knowledge by discussing a topic together. Here too, words have been complemented with other representations, such as argumentative diagrams. Argumentative diagrams are diagrams that show arguments in boxes and relations between them in arrows. They are said to be beneficial for argumentation-based learning, because they display the structure of argumentation, and show relations between arguments (Schwarz, Neuman, Gil & Ilya, 2000; Suthers, 2003). For example, Suthers (2003) found that students focused more on evidential relations when they discussed a scientific topic while also constructing a diagram.

Earlier studies (e.g., Munneke, Van Amelsvoort & Andriessen, 2003) found that students do not benefit much from the construction of an argumentative diagram to learn from argumentation. They find out how to use the diagram fairly quickly, but do not make use of it for relating knowledge. Relations put between boxes are often arbitrary and never discussed. Diagrams are used to display bits and pieces of information, without considering their structure. This finding could be explained in several ways. First, students are not used to constructing diagrams for argumentation, let alone in collaboration. Second, the construction of an argumentative structure might be too hard for students who are used to narrative structures (Chinn & Anderson, 1998). Students might therefore need more guidance in organising diagrams.

In this chapter, we highlight the structural and relational benefits of argumentative diagrams. We investigate whether labelling either the boxes or the arrows in a diagram will help secondary school students to structure their knowledge in such a way that they learn together.

Argumentation and learning

An argument is “a collected series of statements to establish a definite proposition”, to quote from Monty Python’s famous argument sketch. Kuhn (1991) distinguishes between two kinds of argument. The rhetorical argument consists of an assertion with accompanying justification. The dialogic argument consists of a dialogue between two people who hold opposing views. Each person justifies his or her own opinion, rebuts the other person's view, and relates evidence to his or her assertion.

Dialogic argumentation can be beneficial for collaborative learning, because learners have to explain their own viewpoints, and listen and react to other viewpoints. Engaging in a good argument means engaging in a reasoning process (Andriessen, Baker & Suthers, 2003). In a good argument viewpoints are exchanged, support and evidence is given, alternative viewpoints are considered, and counterarguments are rebutted. Counter-argumentation is especially useful for learning, because the reaction to someone's argument enables people to move on from old to new perspectives on a topic (Leitão, 2001).

Argumentation can be used with different goals in mind, such as trying to convince someone your own view is right, or trying to understand the *space of debate*. The space of debate comprises all possible viewpoints and arguments that are associated with a certain discussion. To fully understand an issue, it is important to get to know the different viewpoints, the stakeholders, and their arguments. Arguing with the goal of understanding the space of debate can help students learn about the issue under discussion. Exploring the space of debate is done by collaboratively broadening and deepening it. Broadening the space of debate is described as looking at the different subtopics of an issue. For example, while learners are discussing the desirability of genetically modified organisms (GMOs) they realise that there are environmental factors as well as health factors to consider. Deepening the space of debate is described as elaboration on arguments. For example, learners cannot only give a positive argument for GMOs, but can also give a counterargument, and rebut that counter.

The broader and deeper learners' discussion, the more they can learn. However, a broad and deep discussion does not automatically occur. Both adolescents and adults have difficulties with argumentation, especially with looking at a topic from different perspectives, and countering viewpoints (Chan, 2001; Felton & Kuhn, 2001; Kuhn & Udell, 2003). People tend to simply ignore viewpoints and arguments that do not match their own. One reason for these difficulties is that argumentation is not linear. Viewpoints, arguments and actors are intertwined. It is very hard to get a good grip on the space of debate through temporal linear discussion. Learners may need tools to match linear interaction with non-linear argumentation. In the next section, we will therefore elaborate on the structure of argument.

The structure of argument

Argumentation is not linear (McCutchen, 1987; Coirier, Andriessen & Chanquoy, 1999). An argument is not a straight road from A to B, but a whole structure of roads with shortcuts, u-turns, and junctions. A conclusion is supported with several different arguments. A line of argument supporting a conclusion is undercut with counterarguments and rebuttals. An argument can be related to an explanation and to a counterargument at the same time.

Many people have described the structure of argument. In logical argumentation, the simplest structure consists of two premises leading to a conclusion. Toulmin (1958, Figure 1) proposed a more pragmatic and extensive structure of argument, consisting of six categories displayed in a diagram, namely datum (D), qualifier (Q), claim (C), warrant (W), backing (B), and rebuttal (R). Other researchers, such as Schlesinger, Keren-Portnoy, and Parush (2001) argued that this scheme is not detailed enough. They propose a descriptive framework in which every argument is analysed in a number of related steps, including steps that are implicit in the argument. Although these schemes get more and more complex, they are used to display an argument that leads to one conclusion. They do not incorporate complex argumentation in which different viewpoints and arguments are intertwined. We will return to this drawback in the next section, because we seek to show structure of collaborative argument.

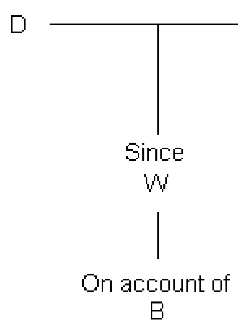


Figure 1. Toulmin's scheme of argument (1958)

Displaying structure in argumentative diagrams

An argumentative diagram is sometimes used in argumentation-based learning. It is not (only) a description of argument, such as the examples in the previous section, but it is used for argument-production. There are two major reasons to use such a diagram in argumentation-based learning. First, it represents the argument's non-linear and multi-relational structure (see Figure 2). According to Harary (1969), the essence of *argument* is structure. The definition of an argument itself is 'a connected graph, in which the arguments are the elements connected through strong and weak relations between them'. Second, according to Anderson (1984), the essence of *knowledge* is structure. Information is remembered and understood by tying an item to a structure that already exists, a mechanism called elaboration (Gray, 2001). Diagrams thus play an important role in learning, because students have to physically represent argumentative information in a structure[7]. We may infer that structure is constructed in concepts and relations by means of argument, and that knowledge is thereby constructed.

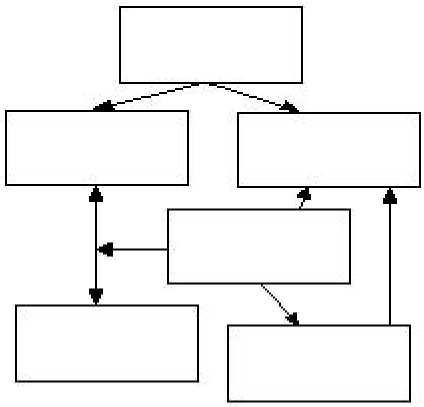


Figure 2. *Argumentative diagram can show non-linearity and multiple relations*

Learning with argumentative diagrams

In the previous section, we related structure to individual argumentation, but our research is focused on dialogic argument and collaborative knowledge construction. Learners are asked to discuss in dyads via the computer, using chat and diagram. According to social constructivists, learning can only occur in dialogue. Learners structure and relate knowledge in collaboration, and incorporate both their ideas into the structure. Knowledge is also co-elaborated (Baker, 2004), by jointly moulding ideas from both learners.

The collaborative construction of argument via chat and diagram has additional consequences. First, the diagram is not used in isolation, but combined with chat. The two concurrently used tools will influence each other. Learners may

[7] We do not want to imply that the external structure of the diagram resembles a structure in someone's head. First, we don't know whether there is such a thing inside a head. Second, the structure is collaboratively made; it should at least represent knowledge of both people working at it.

use chat and diagram for different activities (e.g., Munneke, Van Amelsvoort & Andriessen, 2003), or use both chat and diagram as a mode of communication (e.g., Van Drie, 2005). Moreover, we hope that the structure in the diagram may influence the chat discussion. Chat cannot show a two-dimensional structure, but the argumentative interaction may show more counterarguments, or more weighing of arguments. For example, diagrams may lead to more weighing of arguments in chat. Second, the kind of structure that is represented by the diagram is made in a collaborative exploration of the space of debate. The diagram probably will not consist of one well-supported line of argument, as in the Toulminian diagram. Instead, it will consist of several lines of argument relating different views from the learners and different subtopics. Collaborators can jointly decide on the structure of the diagram, or the structure can arise as a result of two learners working in that diagram. Thus, structure does not need to follow argument strictly, it can also follow the communication between the collaborators. In fact, there are two kinds of structure in a collaborative argumentative diagram. One is a structure within a line of argument, which may consist of a claim, a support, a counter, or a rebuttal. The other is a structure between lines of argument, which consists of relations between different lines of arguments, such as relations between one subtopic and the other. The two lines sometimes intertwine, since a counterargument for a line of reasoning may also show the relation between one subtopic and the other. The within-structure in a diagram makes it easier to set up a line of argument, while the between-structure makes it easier to weigh different views and arguments.

It is this between-structure diagrams are able to show that we are most interested in, because we believe that this structure is important for learning. In order to broaden and deepen the space of debate, learners need to explore the different topics that are associated with the domain, the arguments that accompany them, and the different perspectives that can be taken. More importantly, to make meaning of the space of debate they have to relate these perspectives, arguments, and knowledge. We argue that relating knowledge happens when learners collaboratively elaborate on what they know. We use the term knowledge transformation to describe this phenomenon (cf. Bereiter & Scardamalia, 1987; Baker, 1994). In knowledge transformation, previously unrelated views or arguments learners bring forward in their discussion are explicitly related. This broadens and deepens understanding. Transformations can happen at three levels. First at the level of topic (e.g., in discussing the issue of GMOs the subtopics environment and health are related), second on the level of argumentation (e.g., an argument in favour is related to an argument against), and third on the level of perspective (e.g., the viewpoint of the government is related to that of farmers). A good idea of how the different argumentative knowledge parts are related helps learners discover the complexity and inferences of the issue, and come to a well-supported view.

Labelling structure and relations

Structure and relations may thus well be the most important aspect of a diagram to help students explore the space of debate. However, in previous studies we found that secondary school students do not use this aspect of a diagram well (see chapters 3 and 4; Munneke, van Amelsvoort & Andriessen, 2003). They do relate boxes (arguments) with arrows, but they do not consider the diagram's overall structure. The diagram is used to display bits and pieces of information. Students also hardly talk about the arguments and relations they put in the diagram.

These findings guided us in designing a study in which more attention is paid to the structure and relations in a diagram, by asking students to label boxes or arrows. In the first versions of Belvédère (Paolucci, Suthers & Weiner, 1995), boxes had many labels. This led students to focus on discussing categories instead of discussing content (Suthers, 2001). Belvédère was therefore changed to include only two kinds of boxes, 'data' and 'hypothesis'. However, for diagrams supporting structure and relations between argumentative knowledge-parts, we feel that discussing meta-levels of content might exactly be what is needed.

Two kinds of labelling were developed to support structure and relations in diagrams. In one condition, students label boxes with argumentative terms. In the other condition, students label arrows with more narrative, causal terms. Chinn and Anderson (1998) reflected children's' discussion in either an argumentative or a causal diagram. The argumentative diagram follows argumentation in terms of premises and conclusions. Terms that are used are argumentative, such as claim, argument in favour, rebuttal, etc. The causal diagram follows the line of interactive argument in which two people normally discuss a topic. Thus, argumentation is still used, but in a more causal and narrative way. Although an argumentative structure may sound more plausible to reflect the structure of dialogic argumentation, Pennington and Hastie (1993) found that even in argumentation, people often reorganise information in a narrative structure.

We propose that the dyads in the first condition (label boxes) will be mainly focused on the argumentative within-structure leading to a conclusion. Labelling boxes will help students focus on the deepening activities of counterargument and rebuttal. Dyads in the second condition (label arrows) will be focused more on the causal between-structure. Labelling the arrows will also help them focus on broadening and deepening activities of weighing arguments, topics, and perspectives. Furthermore, we propose that dyads will display a broader and deeper space of debate in the second condition, because it is easier to use a narrative kind of structure than an argumentative kind.

The research questions are aimed at possible differences between co-construction of an argumentative (label boxes) and a causal diagram (label arrows):

(i) What are the effects of co-construction of an argumentative and a causal diagram on how students explore the space of debate?

(ii) What are the effects of co-construction of an argumentative and a causal diagram on transformation of knowledge?

(iii) Do individual students have more argumentative knowledge after collaborating on an argumentative diagram or on a causal diagram?

Method

Subjects

Participants were 46 students aged 15 to 17 from two upper secondary schools in the Netherlands. Two classes participated, one during biology lessons, the other one during Dutch language and literature. The sample included 13 boys and 33 girls. Pairs of students were randomly formed within classes, with each student working at his or her own computer. Pairs were randomly divided into two conditions (diagram with labelling boxes; diagram with labelling arrows).

Task and Procedure

The task roughly consisted of a preparation phase, a discussion phase and a closing phase, in which students worked on the topic of genetically modified organisms (GMOs). The task sequence is described in more detail in Table 1.

Pairs of students were put in one of two conditions. In one condition, they were asked to collaboratively construct a diagram, using the following labels for the boxes: viewpoint, argument in favour, argument against, support, rebuttal, and example. In the second condition, students were asked to collaboratively construct a diagram using the following labels for the arrows between arguments (boxes): because, but, and, thus, such as.

Table 1: *Task sequence*

Phase	Task	Time
Preparation	Introduction of task; short interaction with students on argumentation and discussion; questionnaire on verbal and visual preference and ability; five-minute video introduction to the topic of GMOs. Students received information sources on the topic, and individually made a list with as many arguments for and against GMOs as possible.	90
Discussion	Pairs of students discussed the lists with arguments they made via a computer environment, and collaboratively constructed a diagram reflecting the integration of their arguments. Then they debated about two cases, one at a time, and put their ideas in a diagram. Dyads either labelled boxes or arrows in their diagram, depending on the condition they were in.	130
Consolidation	Individual post-test in which argumentative knowledge of the topic is tested. Classroom debate on GMOs in groups of about 8 to 10 students (not further discussed in this chapter)	60

Note. Time is given in minutes

Materials

Tool. The computer environment we used in this study is called DREW (Corbel et al., 2002) , developed within the European SCALE project [8](see Figure 3). The screen is divided in a chat and a diagram window. Students can make boxes and draw arrows between boxes in the diagram. Every box and arrow can be filled with text.

Information sources. Students received ten information sources to learn about GMOs. These sources were different for each student in a dyad. Both students received positive, negative, and neutral sources on subtopic in the domain of GMOs, but different kinds. For example, both students read a source from the Dutch Oxfam organisation (Novib, against GMOs), but one student read about farmers who become dependent on big factories, and the other student read about a genetically modified potato that is supposed to conquer hunger in the Third World. Students are thus dependent on each other for information, which should be beneficial for collaboration (Cohen, 1994; Johnson & Johnson, 1992).

Assignments. Students worked together on two cases about GMOs, instead of discussing the pros and cons of GMOs in general. This was done to give them more grip on what to discuss. The first case was about whether or not to send genetically modified grains to Ethiopia, a country in desperate need of food. The

[8] The SCALE project, March 2001 – February 2004, was funded by the European Community under the 'Information Societies Technology' (IST) Programme.

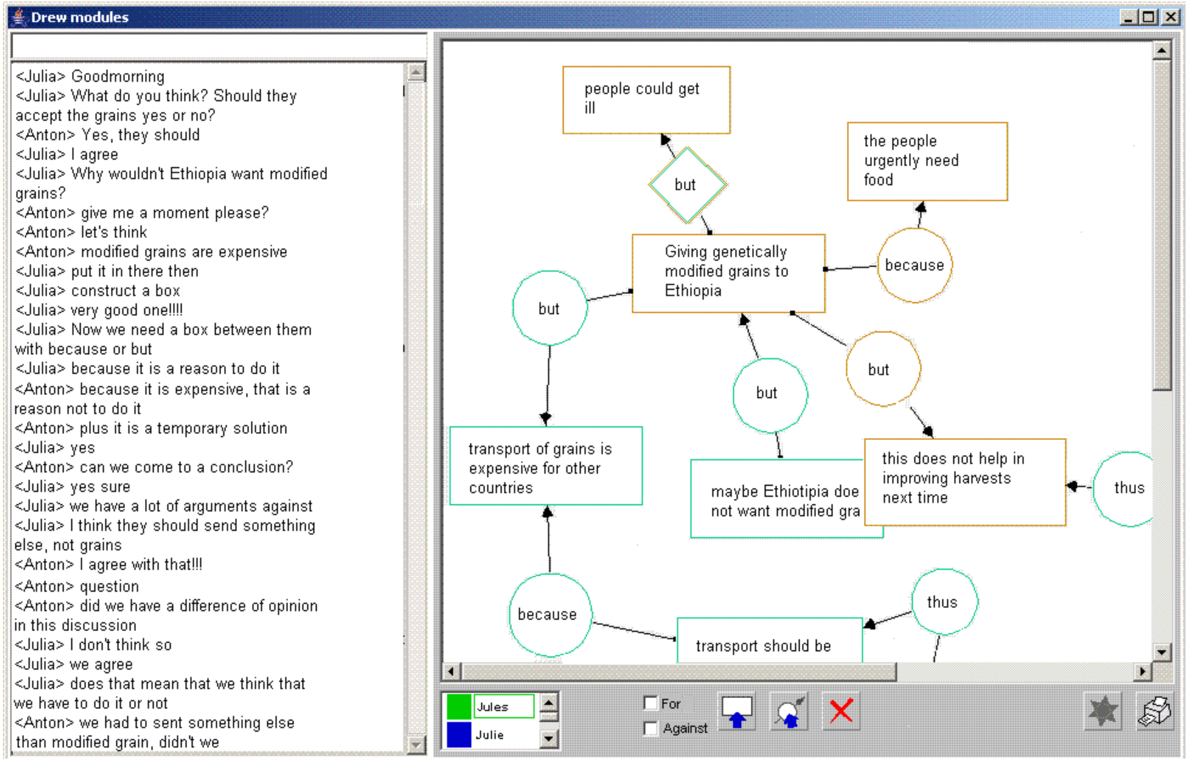


Figure 3. *Screen dump of DREW with diagram window, translated from Dutch into English (labelling arrow-condition).*

second case was about whether or not to genetically modify chickens to be able to have more chickens in a small place, and to have chickens that give more flesh and eggs. Students were specifically asked to consider these cases from different perspectives. Cases were not crossed because of the relatively small number of students.

Test. A test was given to get an idea on students' opinion and argumentative knowledge about GMOs after discussion. Students were first asked about their opinion on the subject. Then they were asked to indicate arguments, themes, and actors in the space of debate. The arguments had to be written down in three columns: the first column for arguments to support the student's opinion, the second column for arguments rebutting their opinion, and the third for arguments to rebut the rebuttals. Portraying the arguments this way should inform us whether students were able to relate arguments. The Dutch test can be found in Appendix C.

Methods of analysis

To answer the first research question into differences between an argumentative and a causal diagram on how students explore the space of debate, we use three kinds of analyses: Rainbow for general activities students perform, broadening and deepening for the extent to which students explore the space of debate, and sequences to understand how students use argumentation in this exploration.

Rainbow. The Rainbow framework (Baker, Andriessen, Lund, Van Amelsvoort & Quignard, 2006) defines students' general collaborative activities in seven categories (see Table 2 below). It provides information on frequencies of activities, e.g., how many of students' activities were aimed at managing the task of constructing the diagram, or how many of their activities could be classified as opinions. It can also inform us about what activities are done where (that is, in chat or in diagram). Categories five, six, and seven comprise argumentative content. Hence, our analysis of exploration of the space of debate in breadth and depth focused on these three categories. Activities are analysed both in chat and in the collaborative diagram. Interrater agreement on ten protocols was .82 (Cohen's Kappa).

Table 2. *Rainbow categories*

Rainbow category	Explanation	Example
1 Outside activity	all remarks that do not relate to the task	How was the party yesterday?
2 Social relation	all remarks about the social relation	You are doing well!
3 Interaction management	all remarks about communication, like checking presence, checking understanding	Hello, are you there?
4 Task management	all remarks and actions for managing the task	It's your turn to write now Creating boxes Reorganising boxes
5 Opinions	all statements about students' opinions	I am in favour of GMOs
6 Arguments	all arguments and counter-arguments students use to support or rebut a statement	Because of genetically modified food hunger in the third world will be banned
7 Explore and deepen	all remarks that explore and deepen the (counter)arguments	But hunger in the third world is not due to lack of food in the world, but to unequal division of food

Broadening and deepening the space of debate. To understand to what extent students explore the space of debate of GMOs, we distinguish between broadening and deepening the space of debate.

Broadening the space of debate is defined as the amount of topics and subtopics mentioned. We distinguish five main topics in the GMOs issue, namely health, environment, affluence, worldview, and other. These topics are further divided into fourteen subtopics (e.g., affluence-hunger/food; affluence-costs/benefits). These topics were defined in advance based on information and students' work in a previous study (see chapter 3).

Deepening the space of debate is defined as students using elaborations and related concepts when exploring an argument or point of view. We follow Kuhn's (1991) argumentative moves to distinguish the different deepening activities. We do not only count frequencies of argumentative moves, but also sequences (see Figure 4). Sequences are temporal series of argumentative moves that are topically related. For example, a discussion often starts with a claim or an opinion. Then someone can give an argument to support that claim, or the other person can give an alternative to show disagreement with the claim. A support can be further supported with evidence, or be countered with counterarguments or evidence. An alternative can be supported with evidence or rebutted with arguments that reject the alternative. In this study, we decided argumentative sequences are especially important, because they show the structure of the argument. Argumentative moves do not get different values (as in chapter 3), but we distinguish different sequences in a discussion by scoring all sequences and the length of the sequence.

Quality of sequences is considered in three ways. First, the longer the sequence within a certain topic, the deeper the argument. Second, certain sequences are considered 'better' than others. For example, a sequence that consists of a claim, a support, and evidence is considered to be better than a claim that is followed by a support but not by evidence. Third, participation within a sequence is considered. It is not important how much each person contributes, because one remark of a student can be more important than ten remarks from his or her partner. However, it is important whether the sequence is created by one student or both, because knowledge construction is assumed to happen in collaboration.

Note that the sequences are scored over chat and diagram simultaneously. A sequence can thus start in chat and go on in diagram for example. Interrater reliability between two judges on 10% of the data reached .75 for breadth and .77 for depth (Cohen's Kappa).

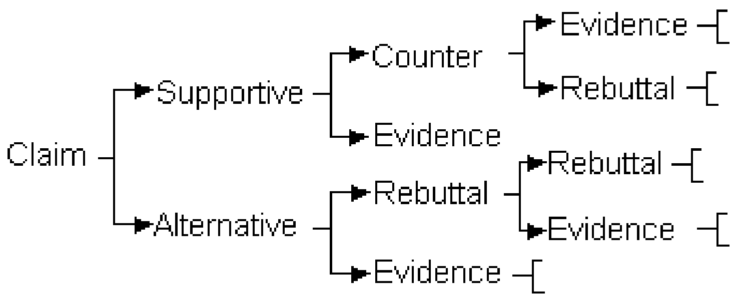


Figure 4. *Sequence of argumentative moves*

We distinguish between three kinds of argumentative sequences (see Andriessen, Erkens, van de Laak, Peters & Coirier, 2003): (1) Minimal argumentation, in which a sequence consists of only one or two argumentative moves, made by one person only; (2) moderate argumentation, in which a sequence consists of two to four argumentative moves, in which both students participate and at least one counter, rebuttal or evidence is used; (3) elaborate argumentation, consisting of more than four argumentative moves in which students negotiate the topic by using supports, counters, rebuttals, and/ or evidence. Moderate and elaborate argumentation can both be considered co-construction, but minimal argumentation is not a collaborative activity.

We do not expect differences in length of sequences, but we do in patterns. Following Chinn and Anderson (1998), we expect more evidence with a causal diagram, but more supportive-counter-rebuttal sequences with an argumentative diagram. Additionally, if a causal diagram indeed leads to more weighing of relations, we expect more sequences made collaboratively with the causal diagram.

Structure and relations. The analysis of structure and relations is specifically aimed at the diagrams students construct together. It can answer the second question on how students transform knowledge together. Every arrow students create in the diagram builds up the structure of that diagram. All arrows from diagrams in both conditions will be analysed on what kind of relation is indicated. We distinguish between first-order relations and higher-order relations. First-order relations are arrows relating a claim to an argument. Higher-order relations relate arguments, for example a supportive to a counter, or a rebuttal to evidence. Figure 5 is an abstraction of a diagram with first and higher-order relations.

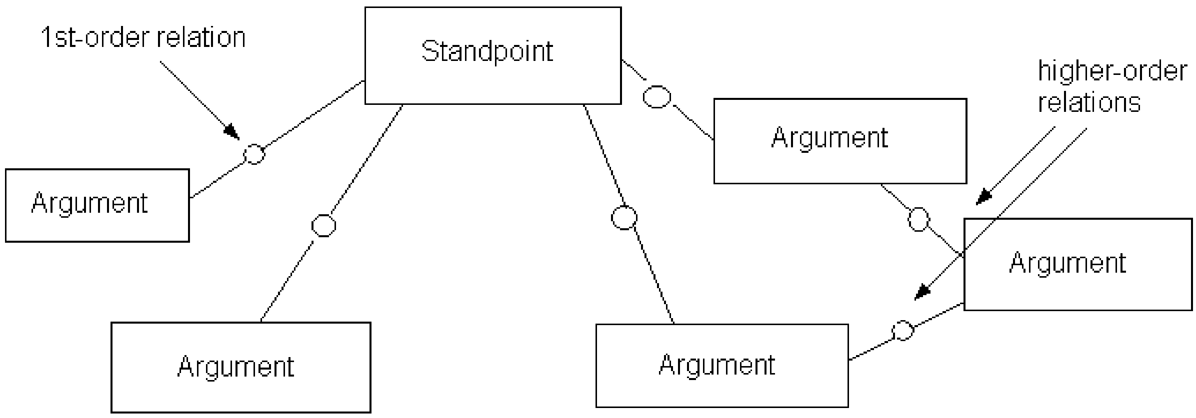


Figure 5. *Diagram with first and higher-order relations.*

The structure within a line of argument can be shown by the sequences described above. In the diagram, this structure is shown by the arrows. However, the diagram should also show structure between lines of arguments. First-order relations can -by definition- not contain a structure between lines of arguments. Therefore, only the higher-order relations are analysed on whether they relate or weigh different lines of argument. We distinguish relations that *contrast topics*, relations that *contrast arguments*, and relations that *contrast perspectives*.

All first-order relations were categorised using Oostdam's (1991) distinction of relations to support an opinion: *cause-consequence*, *comparison*, and *relation of ownership*. In a cause-consequence relation, the claim is portrayed as a cause of the argument. For example: "Caroline studied in France for a year, so she will probably speak French very well". In a comparison, the claim is supported with a similar situation. For example: "We don't have to go abroad on holiday, because they didn't do that in the past either". A relation of ownership justifies a claim with an argument of ownership, for example: "Feike is stubborn, because he is a real Dutchman" - implicitly arguing that all Dutch people are stubborn.

Results

Results are based on chats and diagrams from 18 dyads in the first case, and 20 dyads in the second case. The other dyads were incomplete.

Rainbow

We first performed a Rainbow analysis to see what activities dyads carried out during their collaboration in chat and diagram. Figure 6 displays percentages of

Rainbow activities for the label-box and the label-arrow conditions separately. A division is made between the activities performed in chat and in diagram.

The Rainbow analysis showed no difference between the two conditions in the activities they performed. We did however see a big difference between the activities in chat and diagram. Repeated measures ANOVA of the two cases on rainbow frequencies with Rainbow Category (7 categories) and Tool (two tools, namely chat and diagram) as within-subjects factors revealed significant main effects for Category, $F(6, 240) = 130.38$, $p < .001$, Tool, $F(1, 40) = 39.73$, $p < .001$, and a significant interaction effect, $F(6, 240) = 65.47$, $p < .001$. This means that there are significant differences between activities performed in chat and activities performed in diagram, and that these differences vary between Rainbow categories. The first three categories, the ones not related to the task at hand, are seldom seen in the diagram. In contrast, task management is very often seen in the diagram, and less often in the chat. Content-related activities (Rainbow categories 5,6, and 7) are carried out both in chat and in diagram.

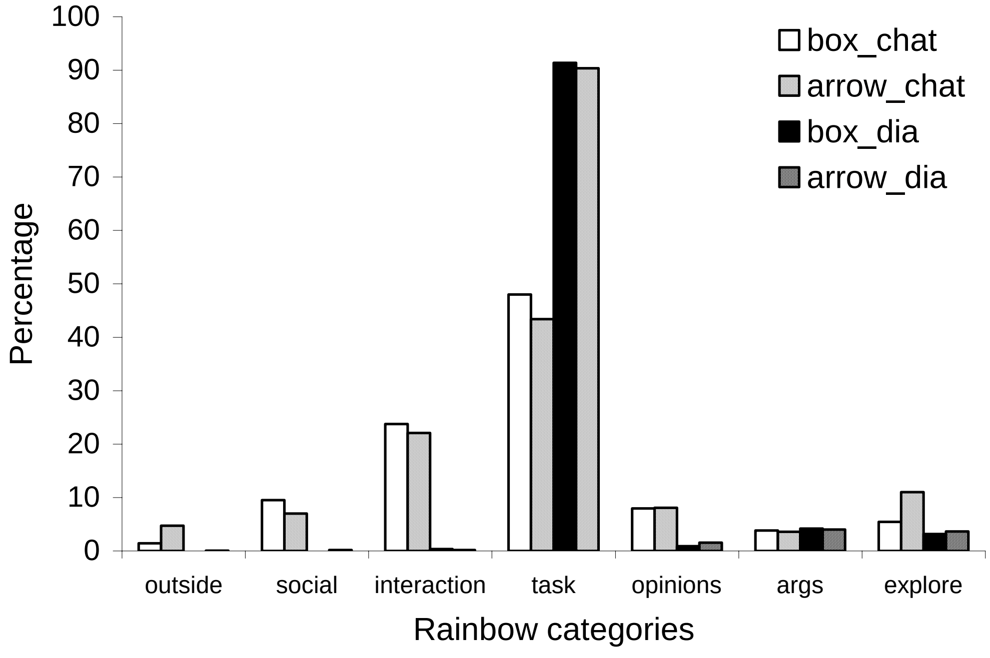


Figure 6. *Rainbow percentages for the two conditions label-box and label-arrow, divided into activities done in chat and in diagram.*

Broadening and deepening the space of debate

Broadening the space of debate was calculated by counting the number of topics students discussed in chat and diagram. Deepening the space of debate was calculated by counting all argumentative moves separately in chat and diagram, and by checking the sequences of argumentative moves. We will discuss sequencing in the next section.

T-tests done on broadening and deepening the space of debate revealed no significant differences between the two conditions. Students in both conditions explored the space of debate to the same extent. Although there was no effect of condition, there was an effect of time. A paired-sampled t-test showed a significant effect of case for deepening the space of debate in chat $t(18) = -2.12$, $p < .05$, and in diagram $t(18) = -2.49$, $p < .05$ when counting all argumentative moves, but not for broadening $t(18) = -1.21$, $p > .05$. Students deepened their second case to a larger extent than their first case. We need to be careful in interpreting the time difference. Because the order of tasks was not randomised, we cannot be certain this effect is due to learning or to difference of the tasks.

In general, students discussed two topics in chat (*SD* = 2.18), and five topics in the diagram (*SD* = 1.50). The numbers of argumentative moves can be found in Table 3. We distinguished between deepening in chat and in diagram. Students either performed deepening activities themselves (give), or asked their partner to do them (ask). As can be seen in the table, students hardly ever ask each other for an argumentative move, except for asking each other's opinion (Ask Claim).

Table 3. *Means and Standard Deviations for deepening the space of debate*

		Chat		Diagram	
Give/Ask	Argumentative move	*M*	*SD*	*M*	*SD*
Give	Claim	2.10	2.09	3.90	2.22
	Support	1.18	1.48	4.58	1.96
	Alternative	.83	1.26	3.35	2.11
	Counter	.33	.76	.80	1.04
	Rebuttal	1.33	3.59	3.10	4.42
	Evidence	1.60	2.47	4.83	3.76
Ask	Claim	1.15	1.58	1.18	1.58
	Support	.25	.49	.28	.51
	Alternative	.03	.16	.03	.16
	Rebuttal	.00	.00	.00	.00
	Evidence	.15	.43	.23	.53

Sequences

Broadening and deepening the space of debate was analysed in the section above by counting the topics and the argumentative moves. In this section, we look at the sequence of the argumentative moves to see to what extent students discuss the space of debate.

Argumentative elaboration. When taking all sequences of 20 pairs in two cases together, 217 sequences could be distinguished. Their length varied between 2 and 14 argumentative moves. A further 123 argumentative moves were not followed by another move (a 'sequence' of 1 move).

A repeated-measures design on sequences with case as within-subjects variable, and condition as between-subjects variable was significant for case, $F(1,17) = 8.51$, $p < .05$, but not for case and condition, $F(1,17) = .10$, $p > .05$. Again the second case showed better results than the first case, but there was no difference between the label-box and the label-arrow condition.

A distinction is made between sequences made alone and in collaboration; a further distinction is made between the tools chat and diagram. Table 4 shows the occurrences of minimal, moderate, and elaborate argumentation. Minimal argumentation, a sequence of only one or two moves made by one person, was found 199 times. Moderate argumentation, in which a sequence consists of two to four argumentative moves, in which both students participate and at least one counter, rebuttal or evidence is used, was found 57 times. Elaborate argumentation, consisting of more than four argumentative moves in which students negotiate the topic by using supports, counters, rebuttals, and/ or evidence, was found 29 times.

Table 4. *Argumentation in sequences*

Argumentation	*N* *Chat*	*N* *Diagram*	*N* *Both*
Minimal argumentation	32	167	-
Moderate argumentation	11	40	6
Elaborate argumentation	14	10	5

Patterns. It is not our intention to discuss all patterns we saw in students' chats and diagrams. Instead, we will focus on sequences in which we expected a difference in conditions.

We expected the students in the label arrow-condition to give more evidence. An independent-samples t-test did not show differences in the amount of evidence asked or given, in either chat or the diagram, on either case (e.g., given evidence in chat and diagram together on the first case, $t(17) = 1.13$, $p > .05$; on the second case $t(17) = .49$, $p > .05$).

We expected the students in the argumentative condition who label boxes to have more support-counter-rebuttal sequences. We also included sequences that contained other argumentative moves, as long as support, counter, and rebuttal were also present. Unfortunately, only 9 of all 217 sequences (in chat, diagram and both) contained a support-counter-rebuttal sequence. Five of these sequences were found in the label-arrow condition, and four in the label-box condition. Table 5 displays an example of an argumentative sequence of support-counter-rebuttal in which two students interact in both chat and diagram (moderate argumentation).

Table 5. *Example of sequence of argumentative moves in chat and diagram*

Student	*Tool*	*Utterance*	*Argumentative move*
Adriana	diagram	Adriana (in diagram) More employment if a part [of the grains] will be used to cultivate	give supportive
Maria	chat	Not more employment, but the old employment	give counter
Adriana	chat	That was gone (work) because the farmers don't need employees if there is no harvest, so no harvesting, so the employment returns	give rebuttal
Maria	chat	That is true	agreement

We expected the students in the causal condition, who label arrows, to have more collaborative sequences. We found that students in the label-arrow conditions produced 74 sequences collaboratively, while students in the label-box condition only produced 55 sequences together.

Labelling the Diagram

The diagram students constructed collaboratively was the most important aspect of the task, since that is where the conditions were different. The students in the label-box condition were asked to label each box with one of six labels given to them (viewpoint, argument in favour, argument against, support, rebuttal, example). The students in the label-arrow condition were asked to label each arrow with one of five labels given to them (because, but, and, thus, such as). In this section we investigate the general appearance of the diagram, and the labels that were used. We want to ensure that the lack of differences we found between conditions is not due to the students not complying with the conditions.

The diagrams in both conditions looked roughly the same; the mean number of boxes in the label-box condition was 9 with 8 arrows connecting them, in the label-arrow condition 10 with 9 arrows connecting them. The number of labels that was used was significantly different for the two conditions; $t(38) = -2.16$, $p < .05$, the label-arrow condition showing more labels ($M = 11.55$) than the label-box condition ($M = 7.83$). In the label-box condition, 71% of all labels were used correctly, that is, a box that was labelled 'argument against' was indeed an argument against. In the label-arrow condition, 80% of all labels were used correctly. We noted that students who were asked to label the boxes oftentimes also spontaneously labelled the arrows, while students in the label-arrow condition did not also label the boxes. In both conditions, students hardly ever talked about the labels in chat (M_{box} = 1, M_{arrow} =.59), which means that there was no discussion about what label to use before putting it in the diagram, nor about labels that were put in the diagram.

In the label-box condition, the labels that were used most were ‘argument in favour’ (26%) and ‘argument against’ (15%). In the label-arrow condition, the labels that were used most were ‘but’ (34%) and ‘because’ (23%). There was a big difference between conditions in how many boxes or relations were not labelled at all; 16% of boxes in the label-box condition were not labelled, while only 1% of the arrows in the label-arrow condition were not labelled.

Structure and relations

The diagram in both conditions is meant to structure the argument, showing how arguments are related. We therefore analysed all relations that students created in the diagram. The relations are the arrows that students put between two boxes in the diagram.

In total, 348 relations between arguments were put in the diagrams, 171 in the label-box condition, and 177 in the label-arrow condition.

Overall, 47% of all relations (162 relations) are first-order relations, which means that they relate the standpoint with an argument. Another 29% of the relations are second-order relations. This means the diagram has a shallow appearance (see Figure 7).

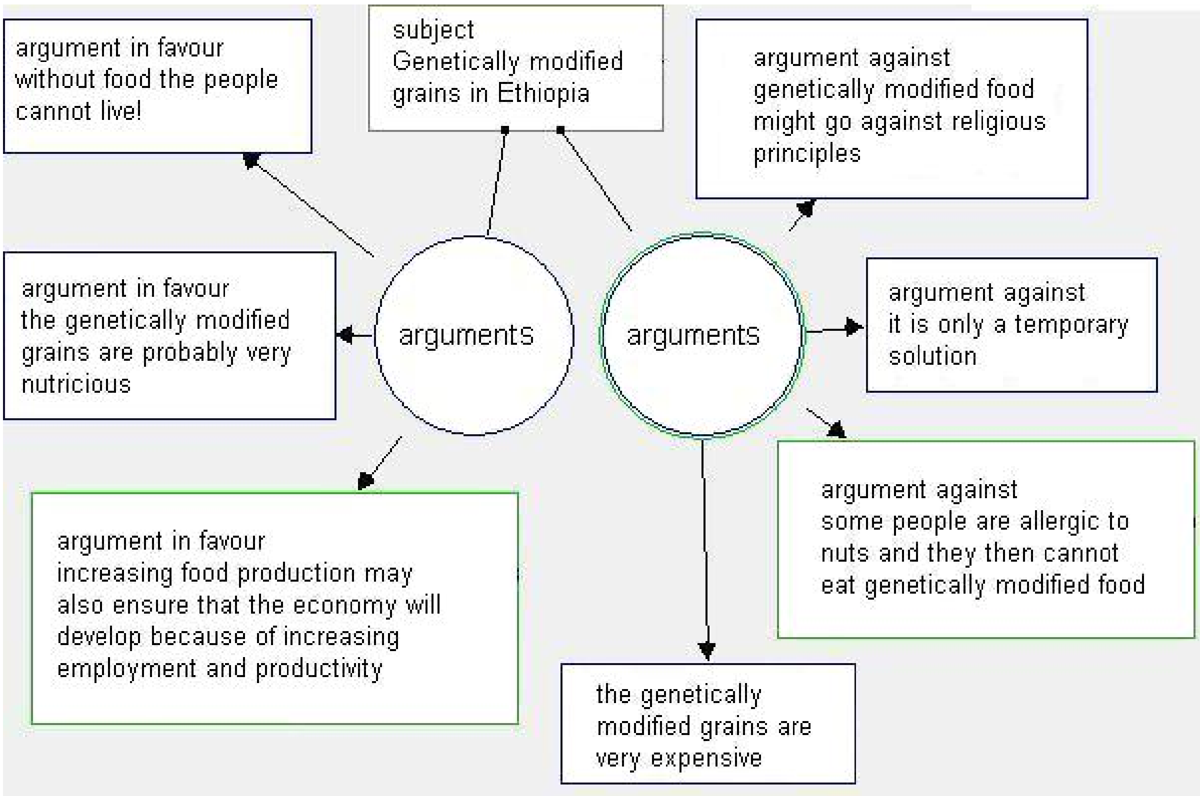


Figure 7. *Example of a diagram in label-box condition with only first-order relations (translated from Dutch into English)*

<u>*First-order relations*</u>. Oostdam's (1991) categories of relations between an opinion and an argument (i.e., cause-consequence, comparison, and relation of ownership) were used to classify the first-order relations between standpoint (opinion) and arguments. We could only score 'cause-consequence', and never 'comparison' or 'ownership'. When checking the content of these cause-consequence relations (and the higher-order relations as well), we noticed that students in both conditions take large steps. For example: "the third world should use genetically modified food → because → there will be no more hunger". All steps in between, such as how, when, and why, are taken for granted.

<u>*Higher-order relations*</u>. Fifty-three percent of all relations (186) in the diagram were higher-order; they related two arguments instead of standpoint-argument. We checked for relations in which students really structure their argumentative diagram in such a way that they see conflicts and can weigh arguments. The three kinds of relations we searched were 'contrast-topic', 'contrast-argument', and 'contrast perspective'. Fifty-five percent of all higher-order relations (102) do not fit one of these categories, because they do not indicate a contrast. A further 29% (54) indicated a contrast in arguments ('good for health because…' versus 'bad for health because…'), 16% (30) indicated a contrast in topics ('good for health' versus

'bad for the environment'), and 0% indicated a contrast in perspectives ('Greenpeace says…' versus 'farmers say…').

A t-test revealed that students in the label-arrow condition created more contrasting relations than students in the label-box condition, $t(166) = -1.97$, $p = .05$. The number of times students contrast arguments is almost equal in both conditions ($M_{box} = 21$; $M_{arrow} = 28$) but students in the label-arrow condition contrasted topics more than twice as much ($M = 20$) as students in the label-box condition ($M = 7$).

None of the relations was a relation in terms of contrasting perspectives. In effect, actors or perspectives in the debate were never mentioned. We never saw the viewpoint of Greenpeace, the government, or the factories. The only actor in the debate that was mentioned in the diagram was the farmer. However, students did not really discuss the farmer's viewpoint, but talked about consequences for farmers (e.g., "farmers won't receive [genetically modified] food, they'll receive seeds").

Test

The test (Appendix C) comprised six questions related to the students' opinion about the topic, and their knowledge about the arguments, themes and actors in the debate. We will first discuss general outcomes of the post-test, and then relate the outcomes to the task and the different conditions to answer research question 3 on argumentative knowledge students have after collaboration on either argumentative or causal diagram.

The majority of students did not change their opinion after discussion compared to before discussion (73%). Only 16% indicated that they changed their opinion after the collaborative task (11% did not answer this question). Students gave several reasons for (not) changing their opinion, such as: "My opinion got stronger", "I did not have a clear opinion beforehand", and "My partner did (not) have good arguments to convince me".

We analysed all answers on the questions to name themes and actors in the debate, and categorized them. Fifteen themes could be distinguished in students' answers, and thirteen groups. Students mentioned 3.71 themes ($SD = 2.01$) and 3.64 ($SD = 1.43$) actors in the debate on average. T-tests showed no significant differences between conditions in how many themes and actors were mentioned.

In question 3, students were asked explicitly to relate arguments. In three columns, they could write down an argument supporting their own opinion, an argument that could counter that, and a rebuttal to show why their opinion was the right one. Students wrote down 3.26 lines of argument on average. They were not always able to complete the whole line of support-counter-rebuttal. In total, students wrote down 8.56 arguments in these 3.26 lines. Each student received a score for the knowledge-related questions in the post-test (lines of arguments, themes, and actors in the debate). T-tests did not show significant differences between students in the two conditions, $p > .05$.

Correlation analyses did not show any correlations between the extent to which students explored the space of debate in their two cases and their scores on the post-test. However, there was a significant correlation between the number of contrast relations from students in the label-arrow condition, and their scores on the post-test ($r_{topics} = .50$; $r_{arguments} = .56$, $p < .05$ on the first case; and $r_{\mathrm{topics}} = .44$, $p < .05$, $r_{arguments} = .26$, $p > .05$ on the second case). Students who put more contrast-relations in their diagram during the two cases in which they worked together scored higher on the post-test. This was only true for the students who labelled arrows, not for the ones who labelled boxes.

Discussion

Diagrams are often used in collaborative argumentation-based learning, because they can display the structure and relations of the argument. This can help learners broaden and deepen the space of debate, and see how arguments in such a space are connected.

The results of our study are mixed. On a positive note, collaborative argumentation while labelling diagrams seems to be beneficial for learning. All students broaden and deepen the space of debate together. Moreover, they used counter-argumentation and especially rebuttals quite regularly. Kuhn (1991) reported that this kind of argumentation is rarely used. The use of counter argumentations appears relatively late in development, from the ages of fifteen to seventeen (Golder & Coirier, 1994), our subjects' age. Thus, the use of counterarguments is probably fairly new to them. Labelling may have accounted for a relatively frequent use of counterarguments and rebuttals; the provision of labels such as 'argument against' for the boxes and 'but' for the arrows may have triggered the students to use this kind of argumentation. We cannot be certain that the labels are responsible for this, because we did not have a control condition in which no labels were used.

The label-arrow condition showed better results than the label-box condition. Dyads in the label-arrow condition constructed a bigger diagram, used significantly more labels, and used a larger percentage of these labels correctly. More importantly, they contrasted different lines of arguments more, especially in the comparison of topics. The argumentative labels in the boxes and the causal labels in the arrows both worked to have students weigh different arguments, but the causal labels worked much better for weighing topics. The more relations dyads create between topics and arguments, the better the coherence in their space of debate. It is not the argumentative structure alone that strengthens the space of debate, but also the causal and topical structure. Students appeared more at ease with the arrow-labels that followed a more narrative, causal structure (cf. Chinn & Anderson, 1998). These labels may have ensured a better relation between the dialogue and the diagram. In addition, the number of contrast-relations students used in the label-arrow condition correlated positively with their scores on the post-test. The weighing of arguments and topics thus contributes to students' argumentative knowledge after collaboration.

If we zoom in on the diagrams dyads created, the picture is less positive. Dyads in fact do not structure and relate their arguments very far at all. Almost half of all arguments are first-order relations, arguments that directly relate to the standpoint. Giving positive and negative arguments for a standpoint does give students a very broad debate, but not a deep exploration of it. If students relate arguments, they take big steps, without considering backing these up. Transformative relations, in which arguments are expanded or founded (Baker, 1994), are rarely seen in this diagram. The lack of explicit structuring and relating knowledge resembles real life. People do not argue often, and if they do, they talk a lot *around* it. The Rainbow results show the same picture. The majority of students' conversation is not argumentative. It is possible that students started building their framework, but simply did not get to the point where they really structure their knowledge.

Another reason why we may not have found the best results is that students need to carry out a dialogic and argumentative interaction simultaneously (Coirier, Andriessen & Chanquoy, 1999). Structuring argumentation may interfere with keeping a dialogue. Many things are left implicit in dialogue, which is no problem in everyday language due to processes as common ground (Clark & Brennan, 1991), or maxims (Grice, 1989). In an argument things are left implicit too. Schlesinger, Keren-Portnoy and Parush (2001) introduced diagrams in which implicit steps were also made explicit, but these are diagrams that are constructed from argumentation by researchers. The diagram students have to construct in our study does not force students to be explicit in every step of the diagram. While we argue that structure and diagrams are important for argumentation-based learning, learners probably do not feel that way. The students did not see the benefits of paying attention to structure. They did not talk about the labels in chat at all, in contrast to students in Suthers' study (2001), who discussed what labels to use at the cost of discussing content. Labelling in our study was probably not seen as an integrated part of the argument construction task. Additionally, the labels were fairly easy to use, which may have led students to conclude they did not need to discuss them.

Our microanalyses tell us that we need to move away from the beautiful claims in literature about diagrams. Diagrams need readership and production skills just like text does (Petre, 1995). As said before (e.g., Hakkarainen, Lipponen & Järvelä, 2002), we are researching effects of certain tools while students are still learning to work with these tools. We found an effect of time - students explored the space of debate further in the second case they discussed than in the first - which may indicate that students are still learning how to carry out these tasks. In studies on writing, it was found that students' texts improved when they were asked to add to their text after finishing it (Bereiter & Scardamalia, 1987). In a next study, we could ask students to focus on structure and relations after they have finished their diagram. We ask them to build their framework, and afterwards, we ask them to strengthen their framework.

Our microanalyses also tell us not to give up too quickly. Although we didn't find immediate effects of labelling the diagrams on broadening and deepening the space of debate, labelling arrows was beneficial for relating knowledge, which even led to individual positive effects after discussion. To make use of this result, we suggest a diagram with an explicit grid-like lay out that could force students to broaden horizontally and deepen vertically. An extra arrow can be imported in the tool that is labelled *weighing* or *contrast* arrow.

To move on with research, we need longitudinal studies, and give students time to improve their reading and writing skills for diagrams. Diagrams have potential, but learners cannot use this potential automatically, even when structure and relations are highlighted with labels.

Appendix C: Post-test

Naam:

Genetische Modificatie

Deze toets gaat over de discussie rondom genetische modificatie. We vragen je niet zozeer om feitenkennis, zoals: 'Hoe kun je organismen genetisch modificeren?' Het gaat om de argumenten, belangen en thema's die een rol spelen in de discussie over genetische modificatie.
Bij sommige vragen staan voorbeelden gegeven om je op weg te helpen. De voorbeelden gaan niet over genetische modificatie, maar over de doodstraf.
Je krijgt 20 minuten de tijd. Succes.

Vraag 1:
Hoe denk jij op dit moment over genetische modificatie? Ben je voor of tegen genetische modificatie?

Vraag 2:
Wat vind jij het belangrijkste argument om voor of tegen genetische modificatie te zijn?

Vraag 3:
Hieronder zie je drie kolommen. In de eerste kolom zet je zoveel mogelijk argumenten die jouw standpunt onderbouwen. In de tweede kolom zet je argumenten die jouw argumenten zouden kunnen tegenspreken. In de derde kolom probeer je die argumenten te weerleggen. Van links naar rechts gelezen hebben de argumenten dus met elkaar te maken. Denk eraan: hoe meer, hoe beter, maar het moeten ook geen onzinargumenten worden! Als je niet genoeg ruimte hebt, kun je op het laatste blad nog doorgaan.

Voorbeeld over de doodstraf (ik ben tegen de doodstraf)

Argumenten voor mijn standpunt	*Argumenten die mijn argumenten zouden kunnen tegenspreken*	*Argumenten die de tegenargumenten kunnen weerleggen*
- Niemand heeft het recht om een ander persoon van het leven te beroven	*Oog om oog, die persoon heeft zelf ook iemand vermoord*	*Maar daarmee maak je de daad niet goed (er is nog steeds een slachtoffer, zelfs twee!)*
- Levenslang opsluiten is erger dan de doodstraf	*Levenslang opsluiten kost te veel geld*	
- De doodstraf houdt mensen niet af van crimineel gedrag *Etc…*	*Maar de doodstraf zorgt ervoor dat de maatschappij niet meer bang hoeft te zijn voor die crimineel*	*In landen waar de doodstraf bestaat, is een groter criminaliteitscijfer dan hier*

Argumenten voor mijn standpunt	Argumenten die mijn argumenten zouden kunnen tegenspreken	Argumenten die de tegenargumenten kunnen weerleggen

Vraag 4:
Noem een aantal thema's dat in de discussie van genetische modificatie belangrijk is.
Tip: kijk in de tabel die je bij vraag 2 hebt ingevuld. Misschien krijg je daardoor ideeën.

Voorbeeld over de doodstraf: (kijkend naar mijn rijtje denk ik aan) ethiek, geld etc…

Vraag 5:
Noem een aantal groeperingen die in de discussie over genetische modificatie belangrijk zijn en die allemaal hun eigen mening hebben over genetische modificatie

Voorbeeld over de doodstraf: kijkend naar mijn rijtje denk ik aan: slachtoffers van geweld, gevangenismedewerkers, burgers die moeten betalen voor ons rechtssysteem, etc…

z.o.z.

Vraag 6:
Ben je door de discussie die je met je partner hebt gevoerd anders gaan denken over genetische modificatie? Waarom wel/ niet?

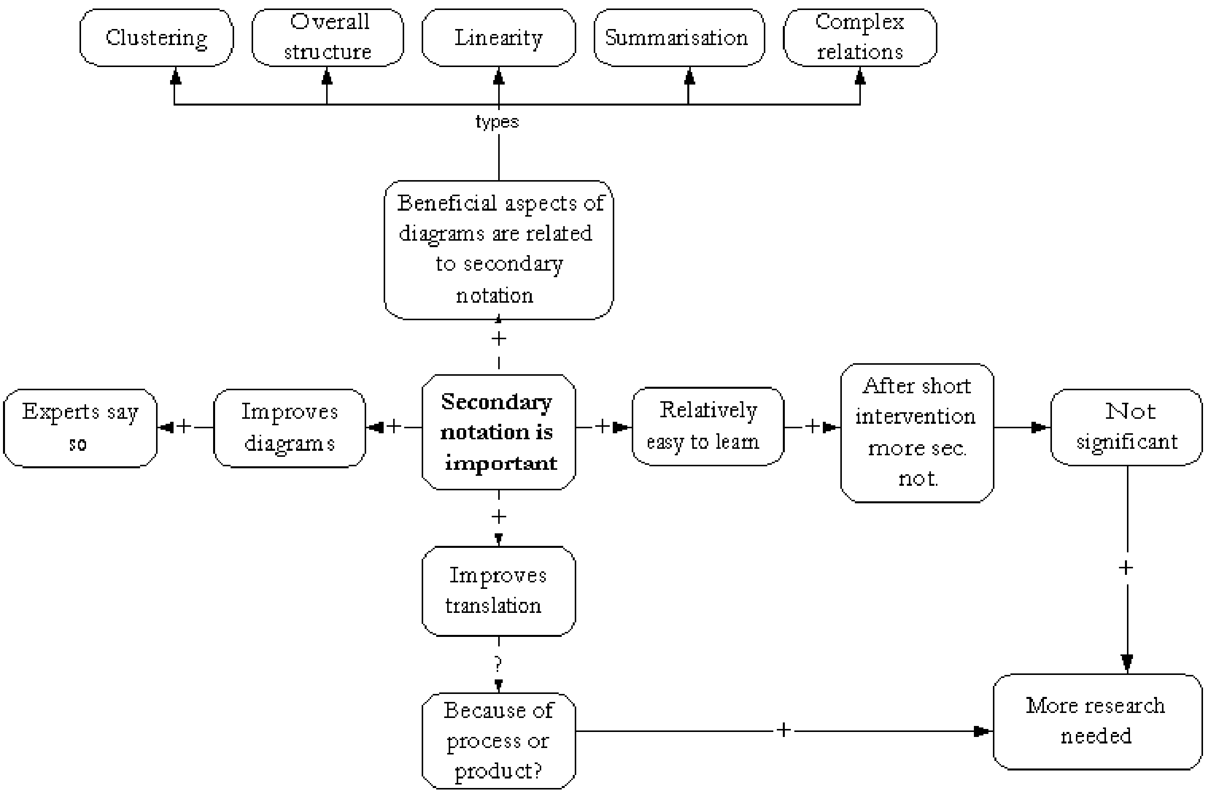
Lever de toets met je antwoorden in bij je docent of bij de onderzoeker.

Eventuele extra ruimte voor het beantwoorden van vraag 2:

Argumenten voor mijn standpunt	Argumenten die mijn argumenten zouden kunnen tegenspreken	Argumenten die de tegenargumenten kunnen weerleggen

6

Supporting notation in argumentative diagrams



Introduction

Using something and really understanding how to use it are two different things. Take a camera for example. Everyone can push the button and take a picture, but knowing how to use light and angle to take the best picture is more difficult. Consequently, people take classes to learn about how to achieve the best effects, they learn by inspecting pictures taken by others or they try alone with practice and reflection. The same goes for argumentative diagrams. Everyone can create boxes, put text in, and draw arrows between different boxes. However, really understanding how to use an argumentative diagram that will help argumentation-based learning is not so easily done. Just like for taking pictures, there are a number of routes by which this expertise may develop. In this chapter, we present a study in which we supported secondary school students in optimising their argumentative diagrams.

We asked students not only to focus on primary features of the diagram, such as creating boxes and arrows with argumentative content, but also on secondary features, such as spacing out the diagram. Green & Petre (1996) use the term 'secondary notation' with examples from programming languages. Primary notation can be described as the 'grammar' of a representation, the formal definition. In argumentative diagrams, the boxes and the arrows are part of its formal definition. Secondary notation, in contrast, can convey extra meaning outside of the formal definition. For example, the use of colour or indenting in programming language does not change the program, but it does help programmers in reading the program. Similarly, although boxes and arrows do not need to be placed in a predefined arrangement, readability can be improved when related boxes are placed closer together.

While students often get the primary notation, they do not often understand how to use the secondary notation of the diagram. In previous chapters, we rarely saw spontaneous use of good secondary notation. This chapter investigates if learners can use secondary notation features after an extremely short intervention describing them. The goal is not so much to guide students to create conventional diagrams, but to help them develop an appreciation of the power of secondary notation in diagrams. This can help students prepare for future learning (Schwartz & Martin, 2004). A subsidiary question is whether the use of secondary notation in a diagram will lead to better argumentative text writing. After a short introduction on representations, collaborative argumentation-based learning, and the use of primary and secondary notation in argumentative diagrams, we present a small-scale study to get a first idea of the power of secondary notation.

Representations

Representations are objects or events that stand for something else (Peterson, 1996). For example, the picture of a cat you take with your camera is a representation of that cat in the real world. Palmer (1978) distinguished between the represented world and the representing world. The represented world is the content, the information or knowledge, i.e., what is represented. The representing world is the computational or symbol level, i.e., how it is represented. In Figure 1 the information represented is the height of Julius and Vincent (represented world), and it is represented in the form of a three-dimensional bar graph (representing world). Because these terms are somewhat confusing, we will use information level for the represented world and presentation level for the representing world.

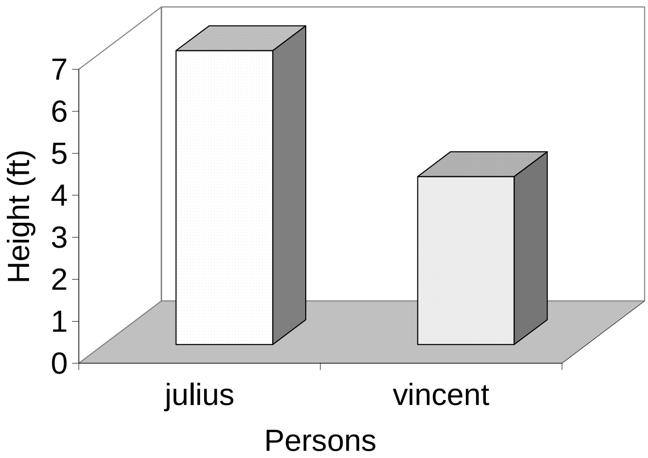


Figure 1. *A graphical representation*

Representations can be equivalent at the level of presentation, while being different at the level of information. For example, the three-dimensional bar graph from Figure 1 can represent height, but also weight of two people. Some representations suit certain information better than others. For example, time is better represented in a line from left to right than from top to bottom (at least in our culture).

Representations can also be equivalent at the information level, while being different at the presentation level (Larkin & Simon, 1987). For example, numbers can be represented in Arabic or Roman notation. The same numbers are represented, but in a different form. The way information is represented influences cognitive processes, e.g., it is more difficult to compute Roman numbers than Arabic numbers (Zhang & Norman, 1994).

Research into representations for learning has a long tradition and is very diverse. Researchers have mostly investigated the effects of visual representations (combined with text) that are given to an individual learner (e.g., De Jong, Ainsworth, Dobson, Van der Hulst, Levonen, & Reiman, 1998; Peeck, 1993; Mayer, 1993). In contrast, we investigate representations that learners *collaboratively construct*. In the context of a collaborative argumentation-based learning task, a dyad of secondary school students is asked to discuss a topic via the computer, communicating in chat and constructing an argumentative diagram together.

Collaborative argumentation-based learning with argumentative diagrams

Collaborative argumentation-based learning is a form of learning in which two or more people discuss a controversial topic together. Argumentation is said to be good for learning, because learners have to verbalise ideas and arguments, and negotiate these. In addition, learners can use each other as a source of information (Stein, Bernas & Callichia, 1997). Learners may thus construct knowledge together, change attitudes or refine concepts (Baker, 1996), and be more aware of their learning process (Gere & Stevens, 1989; Giroud, 1999).

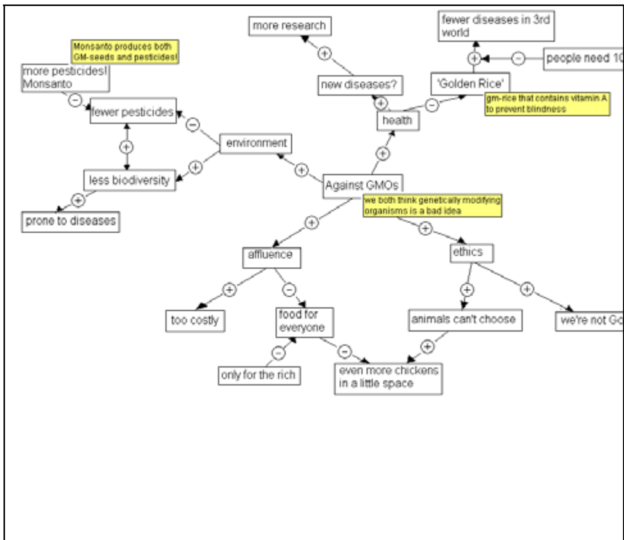
Argumentation is commonly represented in text or speech, but the (additional) use of diagrams can be beneficial for several reasons. First, diagrams can help the communication process between learners, because they are easier to refer to than text (Clark & Brennan, 1991), and can ensure a shared focus and understanding (Suthers & Hundhausen, 2003). Second, they can aid cognitive processes, by displaying the structure of an argument (previous chapter), constraining interpretation (Scaife & Rogers, 1996), and making thinking visible (Bell, 2002). Furthermore, the translation between multiple representations - such as chat and diagram - is related to deeper understanding and looking at the topic from a new perspective (Ainsworth, 1999; Cox, 1999; Seufert, 2003).

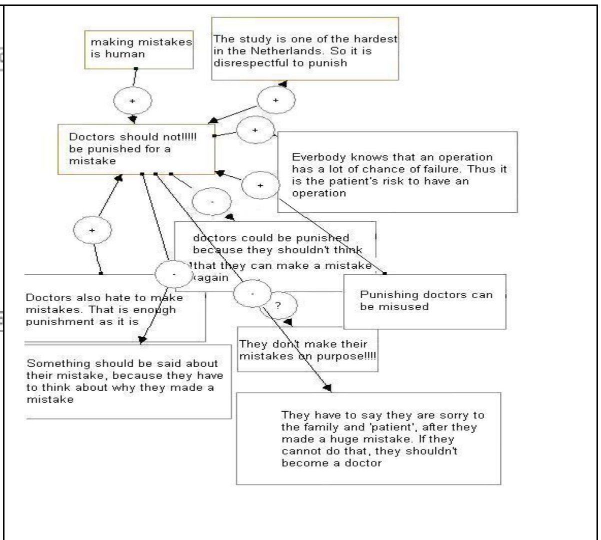
These cognitive functions of representations can also be beneficial when the diagram is used after it is constructed, for example to write an argumentative text. Argumentative texts have special problems regarding content, structure and organisation (Coirier, Andriessen & Chanquoy, 1999). Organising an argumentative text is especially difficult, because of a discrepancy between the argumentative structure and the linearisation of the text. A diagram can help writing argumentative text because information units are ordered and related in a graphical knowledge structure (Erkens, Prangsma, Jaspers & Kanselaar, 2002).

The similarities and differences between textual and diagrammatic argumentation at both the information and presentation levels can be used to the advantage of learning. On the one hand, the diagram constrains textual interpretation (Ainsworth, 1999). For example, positive and negative arrows that signify relations between arguments in a diagram constrain the interpretation of connectives used in text. On the other hand, the diagram makes argumentation visible. For example, the arrows in a diagram clearly show which arguments are related and which are not. We propose that constraints are mostly related to a diagram's primary notation, while visibility is mostly related to secondary notation.

What defines a 'good' diagram?

Figure 2 displays two diagrams. The one of the left is considered to be a good diagram; the one on the right is not so good.





A 'good' diagram	A 'not so good' diagram

Figure 2. *Two diagrams that differ on secondary notation*

The primary notation or grammar in the diagrams is the same: both diagrams use boxes, fill boxes with textual arguments, and relate these boxes. However, the secondary notation is not: the left diagram uses layout, clustering, summarisation, and white space to clarify information, structure and relationships. Petre (1995) argues that secondary notation may well be the principle characteristic that distinguishes graphical notations from other notations, since ´good´ diagrams usually link perceptual cues to important information.

The benefits of diagrams for argumentative learning, such as giving overview (Carr, 2003) and showing structure (Schwarz, Neuman, Gil & Ilya, 2000; Suthers, 2003), are thus as much related to the secondary notation of the diagram as they are the primary notation. Consequently, there is a problem with the use of diagrams in argumentation-based learning; the formal definition of the diagram does not account for a good diagram. Students may know how to create boxes and arrows, but this does not ensure a good diagram. They need to learn how to use secondary notation in diagrams to benefit from them. We will come back to how to support students in using secondary notation below.

The Drew-diagram

The argumentative diagram we have used in our studies is called the DREW-diagram. It is part of a larger computer-environment that also contains a chat facility (Corbel et al., 2002, see Figure 3). The section *Task and learning environment* in the Method explains the use of the environment in our study in more detail. Here we will discuss the DREW diagram to describe its primary and secondary notation possibilities.

In the Drew-diagram, arguments and relations between arguments are represented at the information level, shown in a two-dimensional space with boxes and arrows at the presentation level. This representational format may support cognitive processes such as relating knowledge and comparing different (lines of) arguments.

The primary notation of the DREW diagram consists of boxes and arrows with a positive or negative sign. Students can create boxes with arguments and arrows to relate these arguments. Arrows carry a question mark when students create them, they have to change the question mark into a '+' for a positive relation and a '–' for a negative relation. Extra comments can be made on every box and arrow in the diagram. These comments pop up when students move their mouse over the boxes and arrows (see grey boxes in the 'good' diagram of Figure 2). Students can indicate whether they agree or disagree with the content of a box or arrow by using the tick boxes at the bottom of the screen. If they agree on the content of a box or arrow, two lines in different colours are shown around the box. If they disagree, the box changes in shape (see diamond-shape in Figure 3).

Students can draw inferences on the basis of primary notation that can help collaborative argumentation-based learning. The statements indicate the amount of argument they discussed. The amount of positive and negative relations can inform the students about the balance of their debate.

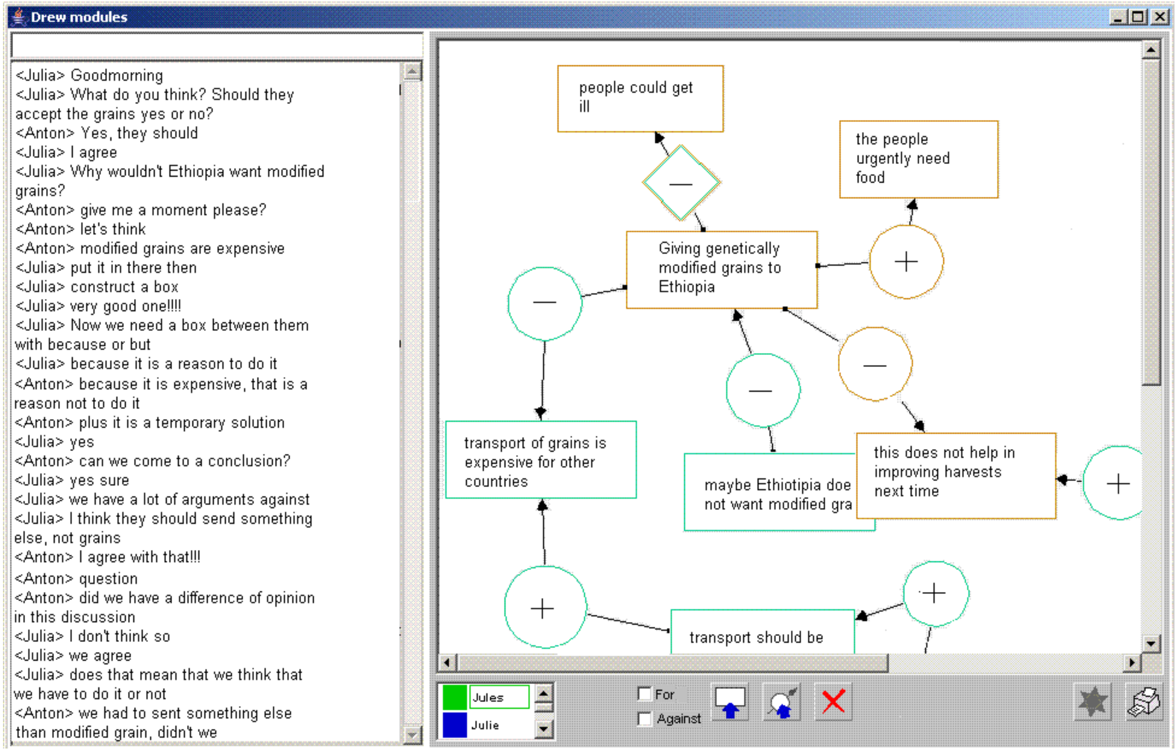


Figure 3. *Screen dump of DREW-environment*

Secondary notation is not defined by the diagram itself. Based on analyses of flaws in previous diagrams, and on discussion with representation and argumentation experts, we distinguished five secondary notations for the Drew diagram. We do not claim to have captured all secondary notations, other experts may come up with additional ones. However, we do claim that these five are important ones that we believe are relatively easy to learn.

- *Clustering*: Related boxes are grouped together. For example, boxes with the same topic are grouped, which also makes the different groups (topics) easily distinguishable
- *Overall structure*: The overall structure of the diagram can give overview of the whole space of debate in different ways. Visibility improves when positive arguments are placed on the right and negative on the left side of the diagram, or when main arguments are placed on top and examples and explanation on a lower level.
- *Complex relations*: Diagrams are able to display multiple relations between arguments, which is not so easily done in chat. For example, an argument can be related to a support, but at the same time to a counterargument. Showing

complex relations with arrows will improve the structure of the argument, which can give students more inside in the argumentative knowledge from the issue.

- *Linearity*: Diagrams show structure of argument. Within a structure, argumentative lines can be distinguished, such as a line from claim to support to conclusion. Visibility is improved when different argumentative lines with non-intersecting arrows are spaced out, while arguments within a line are placed closely together.
- *Summarisation*: If a box contains a lot of text, it will be very large. This impairs overview. A box that contains the text "the cat should be sitting on the mat" could be summarised into "cat on mat". Explanations, if needed, can be placed in the comment boxes, hidden behind the main boxes and arrows. Summarisation improves visibility, but still gives students enough information to translate the content to text.

The distinction between primary and secondary notation is not a distinction between content on one side and structure on the other side. Rather, it is a distinction between the official parts of the diagram that are needed to make one, and the extra meaning that can be conveyed outside of the formal definition. Boxes with text and arrows are necessary for a diagram to be a diagram, but the way information is put in boxes and arrows or the way they are arranged show extra meaning.

The secondary notations that are specifically related to structure show a resemblance to gestalt principles of symmetry and proximity. Kosslyn (1989) argued that, because of the way our perceptual system works, maps configured according to gestalt principles are more effective for learning than maps that do not have these principles. Wiegmann, Dansereau, McCagg, Reqey and Pitre (1992) indeed found that maps made according to these principles led to better encoding and retrieval of information. We have to bear in mind that these maps were presented to individual students, instead of constructed collaboratively.

Students can draw inferences based on the secondary notation. In this study, the inferences they can draw are important for writing a text afterwards. The organisation in the diagram can help students to organise their text. Bromberg & Dorna (1985) have distinguished three kinds of organisation in argumentative texts; 1) discussing all arguments in favour of a viewpoint first, then discussing all arguments against that viewpoint, 2) relating all positive arguments directly to corresponding negative arguments, or 3) an in-depth development of the most important line of arguments integrating possible counterarguments in that line. An overall structure that puts all positive arguments to the left and all negative arguments to the right is easy to translate to the first text organisation. Clearly distinguishing lines of arguments can help students organise their text in the third way mentioned by Bromberg & Dorna. Summarisation may help them get a clear overview of the space of debate they want to discuss in their text. Clustering topics may help them address the different topics in the debate one by one. Clustering participants' ideas may help them address different viewpoints one by one. Complex relations may help them in weighing their arguments in text to come to a well-supported conclusion.

Learning to construct a good diagram

While secondary notation is not defined by the diagram, people can learn to use it. Experts are able to reliably distinguish between diagrams made by experts and those made by novices (Petre, 1995), because of their use of secondary notation. This does not mean that all diagrams made by experts look the same, but that secondary notation is used consistently. For example, one expert may consistently put all procedures in diamond-shaped boxes, and all decisions in circles. Another expert may use different colours to separate arguments from examples.

This study is aimed at supporting students in their use of secondary notation. Students are novices in using argumentative diagrams, and supporting them in constructing representations may help them create good diagrams. Several strategies can be used. For example, Schwartz (2003) had 9th and 12th-grade students construct diagrams individually to display their own representations of a virus spreading. Students came up with many different solutions. After trying to construct a representation themselves, they were offered a representation that displayed the virus spreading correctly and easily. Because students first thought about the problem themselves, and could compare their own solution to the given solution, they understood the advantages and disadvantages of the representations much better. It did not only help them construct a representation, but also understand why to use such a representation. Schwartz & Martin (2004) showed that the process of inventing representations, noticing flaws, and revising them helped students develop insight into the relation between the representation and the represented information. However, these interventions are very time-consuming. Moreover, the representations students construct themselves are compared to the 'correct' representation. The use of secondary notation does not lead to one correct diagram, but to a possible range of diagrams that represent the information level of the diagram in a good way. In short, there may not be one correct representation, but there is a norm: diagrams that use secondary notation in a consistent way are considered better than diagrams that do not use secondary notation, or use it only partly. For example, a diagram in which all arrows cross makes it difficult to see what happens, this diagram is considered not so good because *linearity* is not represented well.

For reading representations, even brief training on strategies has often been found to lead to good results (Schnotz, 2002). The same may be true for constructing representations. We will therefore offer students short guidelines for secondary notation.

Research questions

Our main research question is: *Do students who receive a short intervention on secondary notation produce better diagrams together than students who do not receive such an intervention?* Better diagrams are defined as diagrams that use both primary and secondary notation well, which makes them clearly readable. Although text quality is dependent on many different factors, we will also check to see *whether the improved diagrams will lead to better individual texts*.

Method

Design

We set up a study with two conditions. In the first condition, named Drew, students were asked to discuss in pairs, using chat and constructing a diagram in the DREW computer environment. In the second condition, named Redrew, students were asked exactly the same thing. However, after that, they received an intervention on secondary notation. Then they were asked to improve their diagram based on the guidelines for secondary notation (i.e., they *redrewed*). Students in both conditions wrote an argumentative text individually. The task is described in more detail below.

Participants

Participants were 27 students from two geography classes in secondary education in the United Kingdom. The classes were mixed ability, 11th grade, students aged 14-

15. The study took place at school during the geography lessons. Students worked both alone and in dyads. The teacher assigned them in mixed ability and socially compatible pairs. Three students missed the collaborative lesson, and one student missed the individual writing, leaving seven dyads in the Drew condition and five in the Redrew condition, and twenty-three students writing an argumentative text.

Task and learning environment

Students worked on a task that involved discussion and argumentative diagram construction in pairs via the computer, and individual text writing on paper. They had to discuss the statement “Industrial change improves all our lives”.

In two weeks time, four lessons of 50 minutes each were dedicated to the study. The first lesson involved an introduction to collaborative argumentation-based learning and diagram construction by the researcher. Then the teacher took over and introduced students to the topic of industrial change, and touched upon four countries in particular with different levels of industrial development (more and less economically developed countries, MEDCs and LEDCs). Students were asked to brainstorm individually on issues and facts that could help in discussing whether industrial change is a good or a bad thing. Afterwards they received a paper with issues and sources of evidence that could be used in the discussion. They were asked to do homework on these issues and sources, for example find out the GNP (Grosse National Product) from the four countries. The paper was created by the teacher, and can be found in Appendix D. Students were informed that they would get an effort mark for their collaborative work and an attainment mark for their individual text.

The second and third lesson was a double lesson, in which students discussed the topic in pairs in the DREW computer environment (see Figure 3), using chat and diagram. Students first received instruction on the environment and practiced for 10 minutes. Students in both conditions then worked in dyads with chat and diagram for 40 minutes. The Drew group was then finished. The Redrew group, in contrast, received an intervention on secondary notation (10 minutes). The researcher showed a diagram and asked the group how they would improve on this diagram. Several improvements were demonstrated, and guidelines were given. These guidelines were based on analyses of flaws in previous diagrams and discussions with experts on secondary notation. Additionally, we chose guidelines that were perceived to be learned quite quickly. After the intervention, students were asked to follow these guidelines to improve their diagram in about 15 minutes. The exact guidelines are given in Table 1. The guidelines are respectively based on the secondary notations Linearity, Clustering, Overall structure, Complex relations, and Summarisation. The last guideline is for collaboration; we wanted students to collaboratively improve the diagram, and to discuss how they would improve it.

The fourth lesson was dedicated to individual text writing. All students received the diagram they had made with their partner on paper. They were asked to write an argumentative text (one to two A4) on the statement: "Industrial change improves all our lives", using their diagram.

Table 1. *Intervention guidelines for the Redrew condition*

How to make your argument visible
• Use the whole space (we will give you a printout of the whole diagram, not just the bit you can see at one time). • Cluster related arguments together. Put subtopics together and organise all the parts of the same argument so that you can follow your argument. • Concentrate attention on the most important arguments, for example, by putting these at the top or in the middle. Are the most important arguments also the ones with the most relations? • Look at the relations between arguments – do some of your arguments relate (either for or against) to more than one argument. If so add extra relations (either for or against) to show the whole space of the relationships • Look at your text boxes. Do they have too much text in which makes the argument less easy to follow. You can take text OUT but NOT put any more IN. • TALK ABOUT THESE CHANGES WITH YOUR PARTNER

Analyses

The diagrams students constructed in dyads were analysed on primary and secondary notation. We analysed the diagrams from the Drew-condition at the end of the collaboration, and the diagrams from the Redrew-condition just before the intervention (which equals the end of the collaboration of the other group) and at the end of the collaboration, after the intervention. Table 2 displays the (possible) notations of the Drew diagram, and the corresponding measures we used to analyse whether, and if so how dyads used these notations. Some of these measures could be attained by counting, such as counting the number of boxes or the number of words. For secondary notation, this was not always possible. The last five measures mentioned were rated on a scale from 0 to 2. If dyads did not use this secondary notation at all, they received a score of 0; if they used it but not very well, they received a score of 1; if they did it very well, they received a score of 2. Two researchers scored the secondary notations, and then debated about them until they reached agreement (they reached agreement on all variables for all dyads except one). The scores on the scales were added, so dyads could reach a score between 0 and 10 for the qualitative measures on secondary notation.

Table 2. *Presentation level and measures in Drew diagrams*

Presentation level		Measures in Drew diagram	How
Primary notation	Content of a statement	Content of propositions	name
	Bounds of a statement	Number of boxes	count
	Content of comment	Content of propositions	name
	Bounds of each comment	Number of comment boxes	count
	Relation between statements	Number of arrows	count
	Nature of relation	Number of relations polarised	count
Secondary notation	Complex relations	Number of boxes with complex arrows	count
	Summarisation	Mean number of words per box	count
	Linearity of argument	Spacing out within lines of arguments	0-1-2
	Clustering of statements	Spacing out different lines of arguments visually	0-1-2
	Overall argument structure	Position of the standpoint	0-1-2
		Vertical/ horizontal structure	0-1-2
		Polarisation structure	0-1-2

Another way of checking the quality of the diagrams was by asking experts to rate all diagrams on quality. Experts rated the twelve final diagrams without knowing what condition they were in, or knowing about the content of the two different conditions. We asked them to order the diagrams from best to worst quality. We did not give any hints on what to look at, because we did not want a confirmation that secondary notation was (not) used. Instead, we wanted to know whether the diagrams in which students were asked to pay attention to secondary notation were rated as qualitatively better.

To compare diagrams with text, we distinguished propositions in both diagrams and texts. We describe propositions as (parts) of sentences that form a meaningful unit. In the diagram the box was taken as the unit of analysis, corresponding to the sentence in the text. The boxes and sentences with complex argumentative functions were split into smaller units. For example, the content of the box "Less farmers and what are left are getting paid less" is split in two propositions, 'less farmers', and 'and what are left are getting paid less'. Every unique proposition was then coded. Splitting boxes and sentences was done in close collaboration between two researchers.

Translation between different representations, such as diagram and text, is very difficult for students. Comparing the propositions given in diagram with those in text gives us an indication of how much students have been able to translate from diagram to text. Text quality is further related to many things, such as soundness of arguments, and persuasive power. It is not likely that we see a strong relation between the diagrams and the texts, but if we find a relation, we expect that the use of the diagram is mainly related to structure and linearisation of the argumentative text. Two analyses were used to describe the quality of the results. One is a rating two independent raters gave the texts, based on overall quality of the text, content and structure. The other one is done with automatic CohMetrix analyses (McNamara, Louwerse, Cai & Graesser, 2005) and rates the number of connectives used. Connectives are an important class of signalling coherence relations, especially in argumentative texts, since they can indicate positive and negative relations between arguments.

Results

Our main question was whether students in the Redrew-condition, who received extra information on how to optimise their diagrams, produce better diagrams. A subsidiary question was whether these diagrams lead to better texts.

Diagrams

For both conditions, we analysed the diagrams at the end of the session. For the Redrew-condition, we also analysed the diagrams at the time before they were optimised. The diagrams at the end of the session for the Drew-condition correspond with the diagrams before optimisation for the Redrew-condition, the students in the Redrew-condition had 15 minutes extra time to optimise their diagram.

Note that the sample size is small, which means results should be interpreted with caution. We therefore display Means and Standard deviations, and perform statistical analyses to get an indication of the effect of the results.

Comparison diagram Drew – diagram Redrew before optimising. We expected the diagrams in the Drew- and Redrew-condition to be the same after 40 minutes. At that time, the Drew-group was finished, while the Redrew-group was not yet asked to optimise their diagram. We performed two MANOVA analyses, one on primary notation and one on secondary notation. The MANOVA on primary notation showed a trend between the two conditions, Wilks' Lambda = .31, $F(4, 7) = 3.93$, $p = .06$, $\eta^2 = .69$. Univariate analyses (see Table 3) are not significant between conditions. The MANOVA on secondary notation did not show significant effects between the conditions, Wilks' Lambda = .77, $F(3, 8) = .80$, $p = .53$, $\eta^2 = .23$. Thus, there are marginally differences between the two conditions on primary notation, but no differences on secondary notation before the students in the Redrew condition received their intervention.

Table 3. *Means and Standard Deviations of Drew and Redrew diagram at the same time, before Redrew-diagram was optimised*

	Variable	*M* (*SD*) Drew diagram	*M* (*SD*) Redrew diagram before optimising	*t*[a]	*d*[b]
Primary	Nr of boxes	15.29 (6.78)	14.00 (3.94)	0.38	0.23
	Nr of comment boxes	1.43 (1.81)	2.80 (4.09)	-0.80	-0.43
	Nr of relations	16.00 (7.35)	12.00 (2.74)	1.15	0.72
	Nr of relations polarised	15.29 (7.34)	11.20 (1.64)	1.21	0.77
Secondary	Nr of complex relations	3.14 (2.19)	1.80 (1.10)	1.25	0.77
	Mean number of words in box	11.12 (5.93)	9.74 (3.42)	0.46	0.28
	Secondary notation scale	1.29 (2.63)	2.20 (3.35)	-0.53	-0.30
	Spacing out within lines of arguments	0.29 (0.49)	0.80 (0.84)	-1.35	-0.75
	Spacing out different lines of arguments visually	0.43 (0.79)	0.60 (0.89)	-0.35	-0.20
	Position of the standpoint	0.29 (0.76)	0.40 (0.89)	-0.24	-0.14
	Vertical/ horizontal structure	0.00 (0.00)	0.20 (0.45)	-1.21	-0.63
	Polarisation structure	0.29 (0.76)	0.20 (0.45)	0.23	0.14

Note. t-tests did not show significant effects for any of the pairwise comparisons
[a] $df = 10$
[b] Values of .20 indicate a small difference, .50 indicate a medium difference and .80 a large difference

<u>*Comparison diagram before optimisation – diagram after optimisation in Redrew*</u>. We expected the diagram after optimising to show higher results on all variables of secondary notation, except for relations and secondary notation, but lower results for the number of words per box.

For primary notation, a repeated-measures MANOVA showed a significant effect for primary notation, Wilks' Lambda = .02, $F(3, 2) = 27.48$, $p = .04$, $\eta^2 = .98$, and trends for time, Wilks' Lambda = .42, $F(1, 4) = 5.57$, $p = .08$, $\eta^2 = .58$, and for time and primary notation, Wilks' Lambda = .04, $F(3, 2) = 16.74$, $p = .06$, $\eta^2 = .96$.

For secondary notation, a repeated-measures MANOVA showed no significant effect for time, Wilks' Lambda = .60, $F(1, 4) = 2.66$, $p = .18$, $\eta^2 = .40$, nor for secondary notation, Wilks' Lambda = .25, $F(2, 3) = 4.53$, $p = .12$, $\eta^2 = .75$, or for time and secondary notation, Wilks' Lambda = .29, $F(2, 3) = 3.70$, $p = .16$, $\eta^2 = .71$. The Means in Table 4 are all in the expected direction, but statistical t-tests do not reach significance. However, the difference scores show moderate to large effects.

Table 4. *Means and Standard Deviations of diagrams before and after optimising in Redrew*

	Variable	*M*(*SD*) diagram before optimising	*M*(*SD*) diagram after optimising	t^a	*diff*[b]
Primary	Nr of boxes	14.00 (3.94)	16.00 (4.90)	2.24	1.00
	Nr of comment boxes	2.80 (4.09)	3.40 (5.41)	1.00	0.45
	Nr of relations	12.00 (2.74)	16.20 (5.22)	2.54	1.13
	Nr of relations polarised	11.20 (1.64)	15.20 (4.44)	2.17	0.97
Secondary	Nr of complex relations	1.80 (1.10)	3.40 (1.52)	2.36	1.06
	Mean number of words in box	9.74 (3.42)	9.40 (3.71)	-1.09	-0.49
	Secondary notation scale	2.20 (3.35)	3.00 (2.45)	0.55	0.24
	Spacing out within lines of arguments	0.80 (0.84)	1.00 (0.71)	0.41	0.18
	Spacing out different lines of arguments visually	0.60 (0.89)	1.20 (0.84)	1.50	0.67
	Position of the standpoint	0.40 (0.89)	0.60 (0.89)	1.00	0.45
	Vertical/ horizontal structure[c]	0.20 (0.45)	0.00 (0.00)	-1.00	
	Polarisation structure	0.20 (0.45)	0.20 (0.45)	0.00	0.00

Note. t-tests did not show significant effects for any of the pairwise comparisons

[a] *df* = 4

[b] Values of .20 indicate a small difference, .50 indicate a medium difference and .80 a large difference

[c] No *diff* could be calculated because the mean and standard deviation after optimising were 0

Figure 4 below displays a diagram before optimising and after optimising it. Most noticeable is the difference in relations and in spacing out the diagram. More complex relations are made, making it clear that positive arguments also have negative sides for example. All boxes are related to another box, leaving no loose ends. The thesis gets an important place in the middle of the diagram, showing the start (or end) of the reasoning. The different lines of arguments are now more easily seen, making it easier to read the reasoning of the students, and also presumably easier to write a text following these lines. The students did not summarise the boxes, in fact they added more boxes while we asked them not to do this. They also did not cluster the boxes into topics, views or arguments.

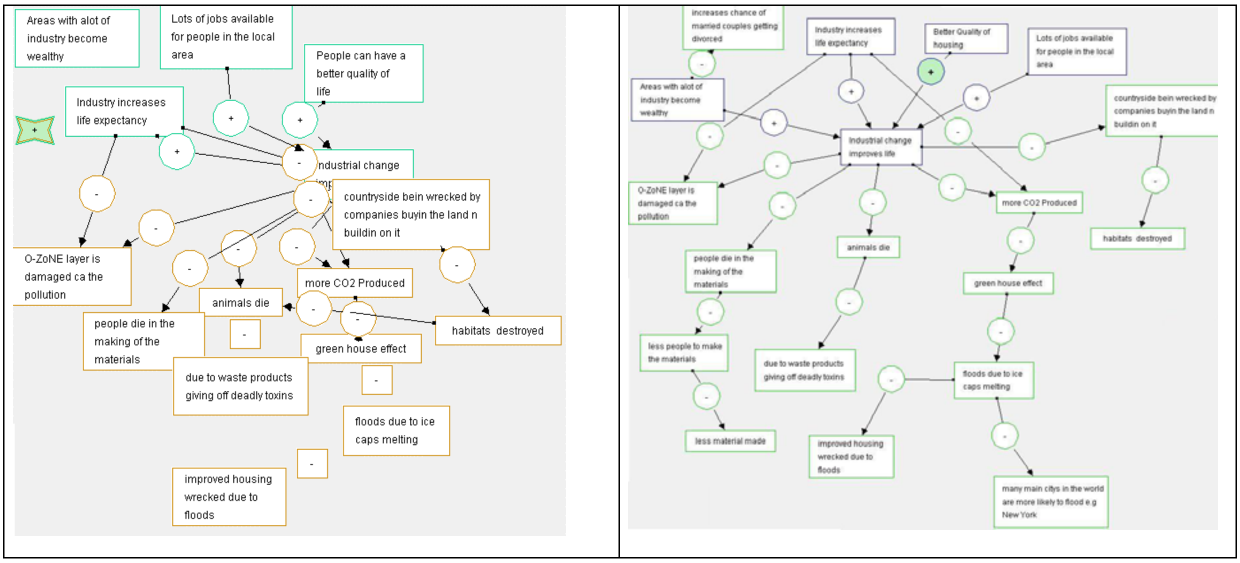


Figure 4. *Diagram before (left) and after (right) optimising*

Quality of diagrams

We asked six experts to rate the quality of the twelve final diagrams (five in the Redrew-condition, seven in the Drew-condition), without knowing about the purpose of the experiment or the two conditions. They were asked to rank the twelve diagrams. We calculated a median rank order of diagrams across experts. According to this median rank order, all diagrams from the Redrew condition were in the first five positions. To make sure it wasn't due to the class being better, we asked four of the experts also to rate the quality of twelve diagrams before the intervention. The five diagrams from the Redrew condition before they were optimised were in positions 1, 3, 7, 8, and 12. To give an example, the diagram in Figure 4 was ranked 8th before the intervention, and ranked 2nd after the intervention on secondary notation. In summary, before students in the Redrew-condition had an intervention on secondary notation, experts did not rate their diagrams differently from the diagrams in the Drew-condition. However, after the intervention Redrew diagrams were ranked higher than Drew diagrams.

Relation between diagrams and texts

To check the relation between the diagrams and the texts, we checked the propositions in the diagram and the propositions in the text. We expected that the optimised diagram in the Redrew-condition would be easier to use for writing the text, so the text in the Redrew-condition should contain more propositions from the diagram. None of the independent-samples t-tests reached significance, but the difference score shows medium effects (Table 6). Students in the Redrew-condition used a higher proportion of their diagram for the text. The proportion of their text that came from the diagram was also higher.

Table 6. *Number and proportion of shared concepts in diagram and text*

Variables	*M (SD)* Drew	*M (SD)* Redrew	*d*[a]
Nr of propositions in diagram	23.57 (10.29)	21.60 (5.68)	0.24
Nr of propositions in text	30.31 (8.45)	27.30 (8.51)	0.35
Proportion of diagram that ends up in the text	0.44 (0.17)	0.56 (0.22)	-0.58
Proportion of text that comes from the diagram	0.35 (0.11)	0.45 (0.21)	-0.44

[a] Values of .20 indicate a small difference, .50 indicate a medium difference and .80 a large difference

Texts

All students individually wrote a text after discussion and collaborative construction of the diagrams. We compared students' texts in the two conditions. We found no significant differences between the two conditions in text quality or connectives (Table 7). Because the grades the experts gave for overall text quality, for content and for structure were highly correlated (*r* ranging from .82 to .97), we only present the overall grade in this table.

Table 7. *Quality of the argumentative texts for Drew- and Redrew-condition*

Variables	*M (SD)* text Drew	*M (SD)* text Redrew
Overall grade	6.88 (.91)	6.20 (1.21)
Connectives	103.35 (20.13)	105.31 (17.43)

Discussion

Some people are naturals when holding a camera; they take the most beautiful pictures. Other people have to take a course to improve their camera-skills. The same is true for working with argumentative diagrams. We did see some dyads that used secondary notation before being pointed at it. However, most of our students needed some support in that area. Our study showed that the use of secondary notation is something you can teach students, even in a short period of time. According to experts, the diagrams that were created after support on secondary notation were better than the diagrams from students who did not have that support. Although the small sample size did not show significant effects of secondary notation, difference scores were moderate to high. The examples of the dyads also show improvement on several aspects of secondary notation.

Not all forms of secondary notation were seen. Dyads created many more relations, but none of the dyads used horizontal and vertical structure in their argumentative diagram. Complex relations, summarisation, and linearity changed more than overall structure and clustering. It appears that not all secondary notations are easily mastered. Three reasons may have accounted for the difficulties students have with some aspects of secondary notation. First, the brief guidelines may not have been enough to demonstrate the more difficult elements of secondary notation. For deep understanding, we expect students would need more time and reflection on the created diagrams, as in Schwartz and Martin's (2004) study to prepare students for future learning. The comparison with a good diagram may help students gain insight in the benefits of secondary notation for reading the diagram and later construction of text. Second, and related to the first point, there could be a problem of motivation or lack of meta-awareness. Just like some people may not be bothered or do not see the need to improve their camera-skills, some students may not care to improve their diagram-skills, especially if they do not see the benefits of improving it for later writing of a text. When students have a better idea of how secondary notation of the diagram can help them in writing their text, it may be easier for them to use the secondary notation to their advantage. They can then choose a strategy. In our experiment, we haven't specifically discussed the benefits of secondary notation for later text writing with the students. A third drawback is the design of the Drew-diagram we used. The space for the diagram is literally quite small. Students can use scrollbars when their diagram is bigger than the part that is shown on screen, but this limits visibility and the benefits of secondary notation. We propose to change the Drew diagram to have more space on the screen, and to minimise space for certain features. For example, the arrows, especially the nodes that show a positive or negative relation, take up a lot of space. Making the nodes smaller or indicating sign by colour could greatly improve visibility.

The relation between diagrams and text is more difficult. Diagrams that used secondary notation well, did not lead to a better text (yet). Of course, text quality is dependent on many variables (e.g., general ability, use of arguments, knowledge of the topic), while the benefits of diagram-construction for subsequent text writing are mainly related to structure and organisation (Erkens, Prangsma, Jaspers & Kanselaar, 2002; Coirier, Andriessen & Chanquoy, 1999). In addition, we guided students in constructing the diagram, not in drawing inferences from diagram to aid text writing. However, we did see that the students used a higher proportion of their diagram for their text, indicating that those diagrams helped text writing better. Moreover, good use of secondary notation seems to lead to increased translation between representations, which is something students normally have problems with (see previous chapters; Ainsworth, 1999). From these results, we cannot tell whether the higher proportion of diagram in text can be attributed to the process of constructing secondary notation, or to the readability of the diagram as a product. A diagram that is easier to read would be easier to translate to text. However, in Chapter 3 we found that constructing a diagram worked better for broadening and deepening the space of debate than inspecting it. A next study could compare students who write a text based on a diagram they made themselves, with students who write a text based on a diagram other students made.

So far, we have studied the benefits of argumentative diagrams when they were far from optimal. This study was a first attempt to change that. Although the study was small-scale, all results showed a benefit of secondary intervention training. This indicates that secondary notation is an important aspect of diagram construction, and something that people can learn to apply. A next study could research the secondary notations that have the most impact. We propose a larger scale study, in which students create several argumentative diagrams for several different purposes, and reflect on their own and others' diagrams. When more is known about the presentation level of these argumentative diagrams, we need to start researching them in a broader view. Information and presentation levels are not the only levels that influence learning with diagrams. Other levels include the cognitive, affective, and the strategic level (Ainsworth, & Loizou, 2003). A very important level for us is the collaborative level. Students created a diagram together. In this study, we haven't specifically looked into the effects of collaborative construction of the diagrams. A structure seems to spontaneously arise between two students, they do not specifically address this issue. A glance at the chats that accompanied the re-drewing revealed that students only communicate task division, such as "I will rearrange the boxes now". A deeper analysis of how secondary notation is used in collaboration is input for a next study.

Appendix D: Paper for homework, provided by the teacher

When discussing “Industrial change improves all of our lives”, think about the following:

- Do you agree or disagree with this statement? Why?
- Listen to each other
- React to one another

What is an argument?
A discussion in which different viewpoints are expressed and reasons for and against these viewpoints are given

- Exchange viewpoints and arguments
- Explain your viewpoints and arguments
- Oppose other viewpoints and arguments
- Weigh different arguments, what conclusion can you reach together?

Why argue in a diagram?

- Gives you an overview of what you have and haven’t discussed
- Structures the argument
- Easily see the evidence for and against an argument
- You can see the points on which you agree and disagree

How to argue in a diagram?
Think about:

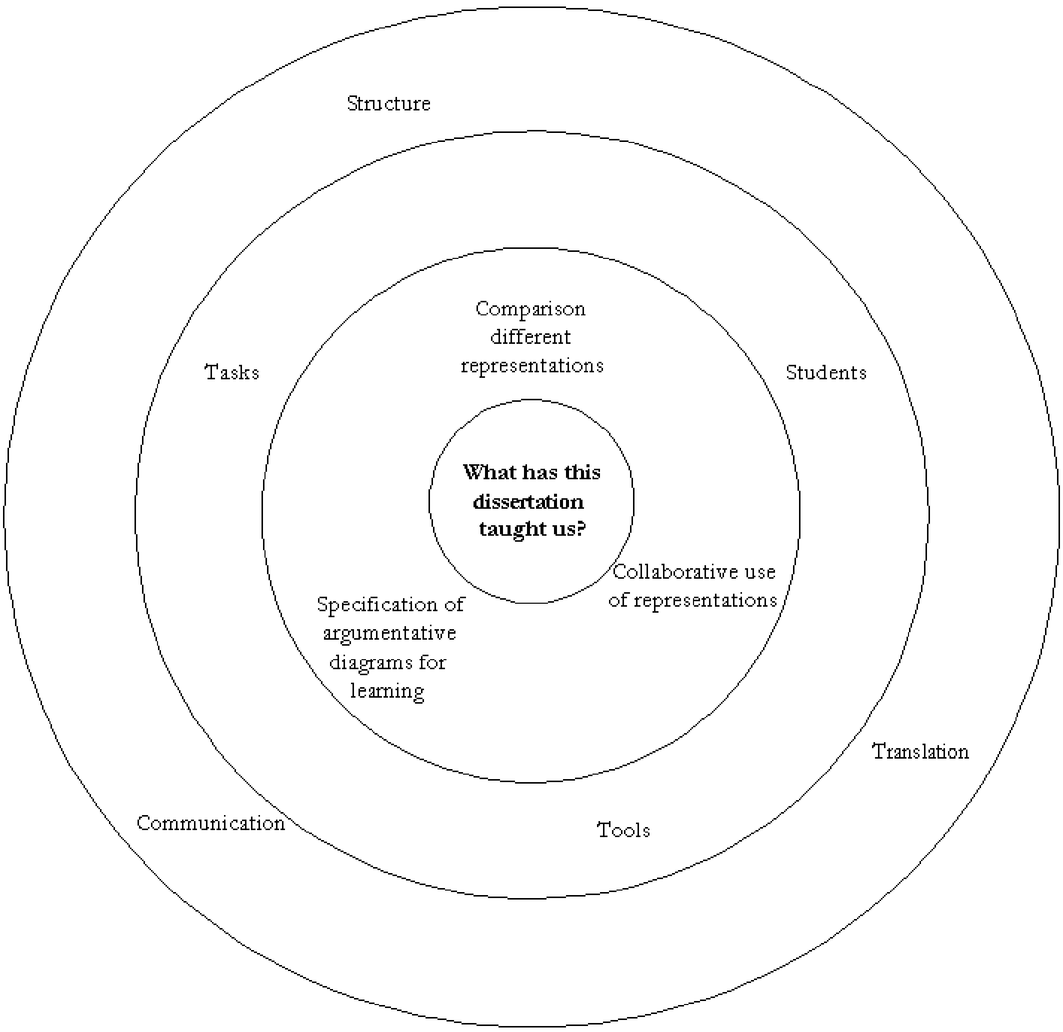
- what you want to put in the diagram
- how to put it in the diagram
- where to put it in the diagram

Use:

- Arguments for, arguments against, examples, explanations, evidence, conclusion
- Arrows between them to indicate the relations → e.g., how does this argument for a position relate to this argument against?

7

Discussion



Overview

The studies in this dissertation attempt to contribute to our understanding of the use of diagrammatic representations to support collaborative argumentation-based learning (CABLE). The research strategy followed was a combination of quasi-experimental design and detailed process analyses. Positive learning effects of CABLE with argumentative diagrams were found, but the studies also revealed issues of how students work with these representations. The results can be placed in three categories that intertwine: results on (1) comparison between different representations; (2) students' collaborative use of these representations; and (3) specification of argumentative diagrams for learning. I will discuss these categories one by one.

Comparison between different representations

Regarding point (1), comparison between different representations, three results are of interest. First, in Chapter 3, I found that students' discussions benefited more from individually constructed diagrams than from individually constructed texts or from given diagrams made from text by the researcher. I compared diagrams and texts that students construct individually to represent their opinion about an issue, before having a debate about it. During debate, students received their own diagram or text and that of their partner to discuss and compare. However, half of the students who wrote a text before discussion received a diagram made by the researcher from their text. The diagrams and texts students constructed before discussion were equally broad and deep, but the revised diagrams after discussion were deeper than the revised texts. Most importantly, the students in the diagram-condition produced the broadest and deepest debates. The diagrams that were given by the researcher did not work very well. The active construction of the diagram is more important for learning than the passive inspection of it. Just the presentation of argument in a diagram is not enough for students to benefit from diagrams. This is in line with constructivist theories mentioned in the theoretical framework (e.g., Bruner, 1990; Von Glaserfeld, 1989).

Second, in Chapter 5, I found that constructing diagrams focused on arrows are more useful for learning than constructing diagrams focused on boxes. Students were asked to discuss two cases on genetically modified organisms (GMOs) and construct a diagram collaboratively. In one condition, the students were asked to label the boxes of their diagram with argumentative labels, such as 'argument in favour' and 'argument against'. In the other condition, the students were asked to label the arrows of their diagram with more causal labels, such as 'because' and 'but'. Although no significant differences were found between the two conditions in the extent to which students broadened and deepened the space of debate, I did find differences in the extent to which students related argumentative knowledge. In their diagrams, students who labelled the arrows showed significantly more relations that described a contrast in topics than students who labelled the boxes. Students who labelled the arrows showed more weighing of argumentative knowledge. This could not only be seen in the diagrams, but also in the results of the individual post-test capturing their argumentative domain knowledge. The way in which certain aspects of argumentation are labelled seems to influence students' reasoning. As Jonassen, Reeves, Hong, Harvey and Peters (1997) put it, "Cognitive tools […] constrain the ways people organize and represent ideas, so they necessarily engage different kinds of thinking" (p. 293).

Third, in all four chapters reporting experimental studies (Chapters 3, 4, 5 and 6) there were no straightforward relations between different representations used in parallel or subsequently in a task. In all studies, discussion in chat was accompanied by collaborative construction of either diagram or text. I expected overlap (integration) between chat and diagram, for example from students discussing a topic in chat and then putting it in the diagram or the collaborative text. Another possibility was that students would use either chat or diagram to explore the space of debate, but not both. However, hardly any positive or negative significant (cor-)relations between the different representations were found. In Chapter 4, I zoomed in on the flow of discussion between students and tools, and found that students have problems translating between different representations. I described two students who really refined and changed their argumentative knowledge in chat together. However, when they started constructing their diagram, they resorted to copying arguments that were already present in their individual diagrams, instead of translating their chat discussion to the diagram. To conclude, we cannot expect that using multiple representations such as chat and text are better for learning than using single representations (e.g., Boshuizen & (Tabachneck-) Schijf, 1998), because students often treat them as separate and unrelated (see also Veerman, 2000; Munneke, Van Amelsvoort & Andriessen, 2003). Translation between representations requires a lot of mental effort. Students will probably not translate if a task can be carried out without that mental effort.

Students' collaborative use of representations

Regarding point (2), how students collaborate in using representations, I found that students work very differently at CABLE-tasks. In Chapter 3 students worked in the TC3 environment in which they could discuss in chat and write a text together. Some dyads work mainly in chat, while others work mainly in text. Additionally, the same representation is used in different ways. For example, some students used individually made diagrams during collaboration to tell information, while others used it as input for an elaborative discussion (Chapter 3). Similarly, when students chat and construct diagrams together some copy arguments from chat directly to the diagram, while others refine or change arguments from chat to diagram and vice versa (Chapter 4). Differences within conditions were higher than differences between conditions. Differences between dyads seem to be more related to the extent to which they were actively engaged in exploring the space of debate than to the specific 'features' of the conditions. For example, students who are really trying to explore the space of debate together transform knowledge, while students who are aimed at finishing the task quickly and individually do not build knowledge (Chapter 4). Students' collaboration may depend on their social relation (see Van Amelsvoort & Andriessen, 2004), but also on their perception of the task. I will come back to that point later. Individual variables could also be related to students' task execution, such as experience with and attitudes on collaboration, argumentation, and diagrams. An article on these individual variables is in preparation (Van Amelsvoort & Breugelmans, 2006).

Specification of argumentative diagrams for learning

Regarding point (3), specifying argumentative diagrams that can support learning, secondary school students were found to learn from collaborative argumentation-based tasks with argumentative diagrams. In all studies texts and diagrams made individually after discussion in Chapters 3 and 4 were broader and deeper than those made before discussion. This finding does not necessarily mean that collaborative argumentation with diagrams is responsible for the effect, it could be also just a time-effect. Also, it doesn't tell us what a diagram should be like to support learning. Therefore, the emphasis of all studies in this dissertation was on the process of collaborative argumentation-based learning with diagrams.

Second, I showed that a diagram can be implemented in a learning task in different ways, such as individually before discussion, collaboratively during discussion, or collaboratively after discussion (Chapters 3, 4, 5 and 6). In different phases of a task sequence diagrams have different functions – which implies that the decision to use a diagram should depend on the task goal. A diagram constructed individually before discussion can help students organise their own ideas, and can help them in later comparison of ideas with their partner. A diagram constructed collaboratively during discussion can be used as input for further discussion. A diagram constructed collaboratively after discussion can be used to reflect on the outcome of the debate.

From a researcher's perspective, revising a diagram individually after discussion is probably not the optimal way of finding out to what extent students have learned. Students did not change their diagrams much. One reason for this could be lack of purpose: They seemed not to see the need of adding arguments and restructuring their diagram. An alternative idea is to ask students to construct a new individual diagram after discussion instead of asking them to revise their previously created diagram. However, the UK-team in SCALE did that, and it did not work either. The representation of the space of debate in new post-task diagrams was less elaborate than in the countries in which an existing diagram had to be revised (SCALE-team, 2002). Another explanation for the problem of creating post-hoc diagrams could be translation. The post-hoc diagram probably did not capture students' knowledge about the space of debate after discussion (Bell, 1997), because it is too hard to capture knowledge into an external representation. Probably both explanations have some merit. For learning purposes translation seems important, therefore, although this assumption was not tested, it may be a good idea for students to construct an individual representation after discussion that is different in modality from the representation students have used in collaboration.

Third, structure and relations were found to be among the most important features of argumentative diagrams (Chapter 5). The most noticeable difference between diagrams and textual representations is the fact that diagrams show structure in a two-dimensional space. A diagram can support collaborative argumentation, because argumentation is not linear (McCutchen, 1987; Coirier, Andriessen & Chanquoy, 1999). In Chapter 5, it was found that having students focus on the relations between arguments by asking them to label arrows helped in exploring contrasting topics in the argument. When students are not specifically asked to focus on structure and relations, they often display bits and pieces in the diagram, and use arbitrary relations. However, I also found that students hardly talk about the diagram, what it looks like, or what it should look like. A conclusion that can be drawn is that the design of the diagram can help students focus on certain aspects of collaborative argumentation, which may change their reasoning. However, we have to support students in using diagrams more purposefully.

Fourth, in Chapter 6 it was argued that secondary notation is very important for argumentative diagrams. Secondary notation is described as the meaning that can be conveyed in a diagram outside of its formal definition. For example, the boxes and arrows in an argumentative diagram are part of its formal definition. The way these boxes and arrows are organised in space is not formalised, but can convey extra information. The benefits of diagrammatic representations for learning that are mentioned in literature are as much related to secondary as to primary notation. I found that secondary notation is relatively easy to learn. After a short intervention on secondary notation, students improved their diagrams to show more secondary notations. Experts rated these diagrams as better than diagrams from students who did not receive an intervention on secondary notation. There was more translation between the diagram and the individually written argumentative text for students who were taught secondary notation than for those who were not. Whether this relative ease of translation was due to the process of constructing the diagram, or to the final appearance of the diagram (as a product) deserves further investigation. In short, it was shown that students can use secondary notation, but they do not spontaneously use it. This finding may be related to the fact that students do not see the added value of secondary notation for their task (in this case: individual writing). Although I argued above that diagrams can be designed in certain ways to have students focus on certain learning activities, the issue of secondary notation also highlights the importance of focusing on how students build diagrams.

All results point to the same direction: argumentative diagrams in CABLE work, but they could work better. Not unlike learning in other complex tasks, beneficial learning processes only occur in certain circumstances. The quasi-experimental conditions in the studies described in this dissertation have shown the nuances of diagrammatic support for CABLE. Reasons and implications for these findings lead us in two directions. First to the benefits of argumentative diagrams, comparing the theoretical and practical support argumentative diagrams offer to get more grips on how diagrams work. Second to the students, how they work with the diagrams, and how we can improve students' activities in argumentative diagrams.

Specifying argumentative diagrams for CABLE

Argumentative diagrams are strange representations. They combine textual and visual information in one representation. On the one hand, the text in an argumentative diagram is very important, since this represents the arguments of a debate. On the other hand, too much text undermines the visual strengths of a diagram. Four possible benefits of diagrams for learning were mentioned in the theoretical framework: concreteness, overview, structure and relations, and stimulus and guide of communication and reasoning. However, the first three benefits are less apparent when a diagram is too *texty*. Van Drie, Van Boxtel, Jaspers & Kanselaar (2005) found that diagrams are less suitable to contain a lot of information, compared to matrices and lists. Although organisation and interrelation are important theoretical benefits of diagrams, diagrams may get too hard to organise when a lot of information is represented. Their findings are in line with findings from our questionnaire into preference and ability (Van Amelsvoort & Breugelmans, 2006), in which diagrams were preferred over text when represented information was moderately complex. When information is very simple, a diagram is not advantageous over text. When information is too complex, the diagrams become too difficult to keep overview or to have them neatly organised.

A good argumentative diagram contains enough textual arguments to make a point. It does not use too many words to make this point. It shows relations between arguments and counterarguments to indicate the organisation of the space of debate. It shows structure to give an overview of important and less important arguments. It uses space to distinguish between different lines of argument. In short, the secondary notation (Chapter 6) of the diagram is used well.

The fourth benefit, a diagram as stimulus and guide of communication and reasoning, is less influenced by the amount of text in the diagram, although visible structure is also important for reasoning. This benefit is not always explicitly shown. When diagrams are used to indicate individual ideas before discussion (as in Chapter 3), students sometimes explicitly refer to them to indicate (dis)agreement or to ask for clarification. However, when a diagram is made collaboratively during discussion, communication via the diagram can be much more implicit. Students finish each other's argumentative lines, change or delete their partner's arguments without negotiation. In general, the diagrams were not used as a stimulus for argumentative interaction in chat. In summary, the specific characteristics of an argumentative diagram - a texty diagram with arguments in boxes and relations between them in arrows - partly determine its benefits for CABLE. However, this is not the only factor that specifies how diagrams can (not) support collaborative argumentation-based learning.

Variables influencing argumentative diagrams for learning

Following the line of reasoning from above, a diagram is not automatically beneficial for CABLE. Besides the fact that we are talking about a specific 'texty diagram', the benefits of such a diagram depend on the task that has to be carried out. For example, if the task is to structure arguments, the benefit of the diagram is based on the fact that argumentative structure can be displayed with arrows. The affordances of the diagram may also be dependent on other tools in the task, such as chat. If chat accompanies the diagram, the affordances of a diagram as a means to communicate may be less apparent than when a diagram is used without chat.

The benefits of a diagram also depend on what the diagram looks like, or to reverse that statement: the appearance of the diagram accounts for the benefits a diagram conveys. For example, a diagram that contains a lot of information does not have the benefit of providing quick overview.

Task and diagram can be manipulated by teachers or researchers, as I have done in placing students in different conditions. However, the student is the most important link in determining and using the benefits of the argumentative diagram. First of all, the benefits the diagram can offer depend on how the students use it. For example, if students use a diagram to display bits and pieces of information, the possible benefits of structuring the debate cannot take effect. Second, the task as provided by the teacher or researcher is mediated by what students perceive it to be. For example, if students think they have to make a diagram with arguments in favour of their standpoint, they may not weigh different arguments in the diagram, even though the researcher would like to see that. Third, because argumentative diagrams are constructed by the students themselves, they are the ones who 'decide' what the diagram looks like. If students use secondary notation in their diagram, they can benefit from its appearance to broaden and deepen the space of debate. In schema:

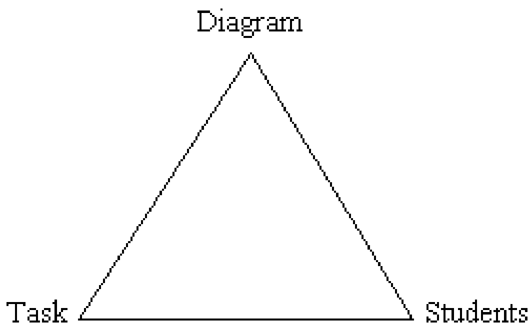


Figure 1. *Factors in how diagrams support CABLE*

Before I move on to discussing the triangle in light of the studies presented in this dissertation, a word of caution. External representations like this triangle always simplify reality. For example, the three corners of the triangle are not static entities. Students, task, and diagrams may change during the course of collaborative learning. The perceived task changes during the process. For example, our analyses show that most students start by exchanging viewpoints and arguments in chat, and then move to construction of the diagram. Arguments are placed in the diagram first, and then the students move on to shuffling boxes. Also, students can change during the task execution. For example, students' attention can fade, or they learn how to use the diagram during the task execution, or the relation between the two students changes throughout the task because of their collaboration. We have seen examples of students who gradually seemed to collaborate better. This was especially the case for students who normally did not work together or were no friends. Because of their collaboration, they seemed to realise they liked each other more than they thought. For other students, the opposite was true. The dyad in Table 1 had a very good discussion at the start of their collaboration, but when one student did not participate in constructing the diagram, the two students got into an online-quarrel.

Starting at the top of the triangle

The triangle in Figure 1 can be explored by starting at each of the corners. Here I will start from the top by discussing the diagrams I have seen in my studies. All diagrams students made looked different, but they can be divided in two broad categories. The first category consists of diagrams in which students communicate; the diagram is used as medium for discussion. The second category consists of diagrams in which students collect positive and negative arguments around a statement; the diagram is used as a reflection of the space of debate.

Figures 2 and 3 are examples of the first category. The diagram in Figure 2 was made by a dyad in a pilot study that was done when the first version of Drew was ready (not part of this dissertation). This diagram is the clearest example of what it could mean to really discuss 'through' the diagram. The dyad used the boxes to put (argumentative) titles in, and used the comment boxes to put the arguments in. The arguments themselves are thus only shown when moving your mouse over the box. Every sub argument has its own line, and ends with a conclusion, such as "I don't have a better counter for this one and it is a good argument so I have to go along with this one…", or "this is about facts, not about opinions, I won't answer this one".

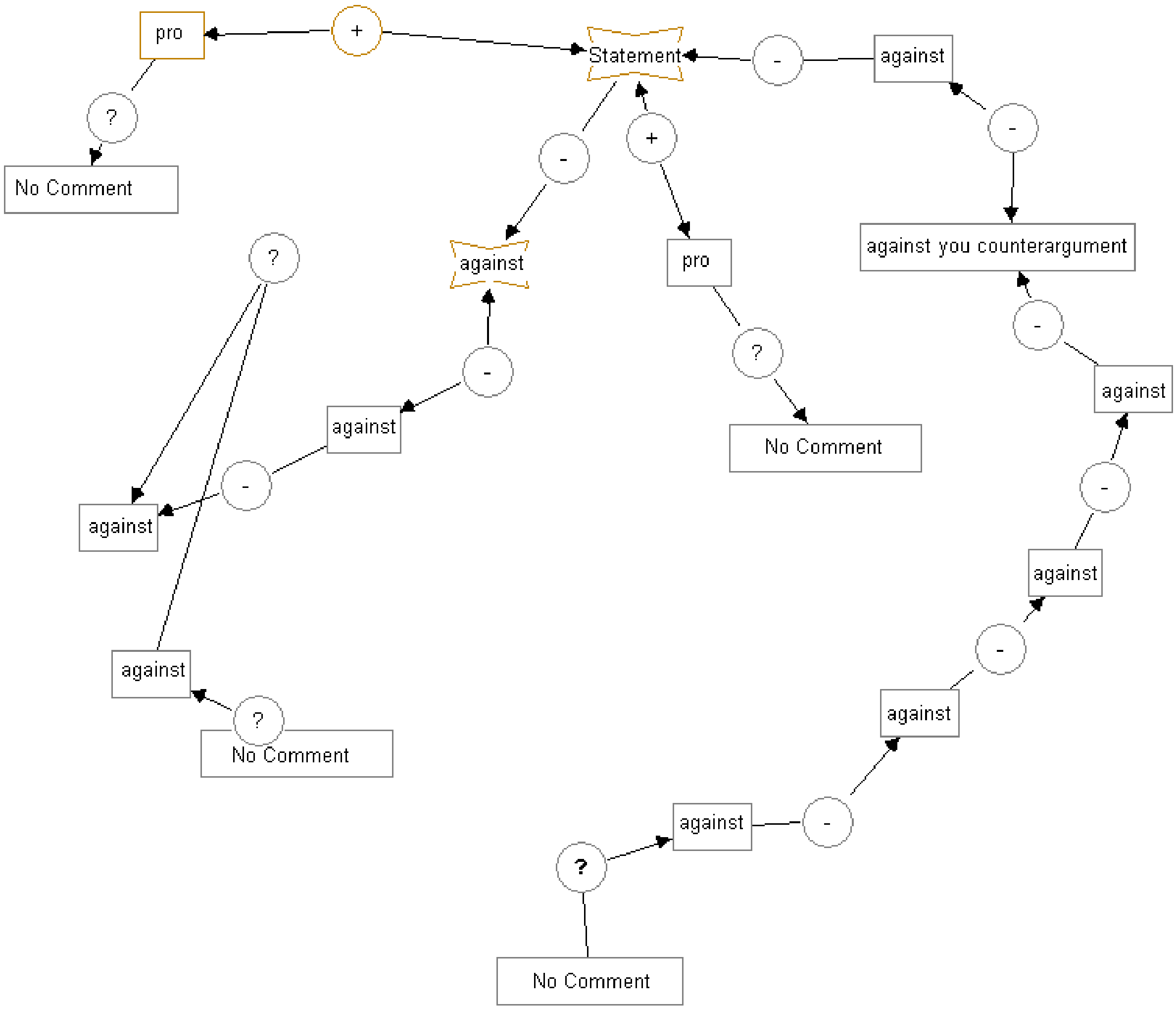


Figure 2. *An example of discussion through the diagram*

The diagram in Figure 2 shows that students have essentially deepened their space of debate. They have four arrows coming from the main statement, two in favour, and two against. Thus, they have not broadened the space of debate much, but two of the lines are deepened to a fair degree.

It is difficult to understand how and why the students constructed this particular diagram. One student started with constructing a box with 'statement' in the title, and the content of the statement in the comment box. A little later that same student proposed: "you make up an argument against, then I'll make up an argument in favour (against your counterargument), and then the other way around". His partner agreed in chat, and so the diagram structure was settled. These students have interpreted the task as an argumentation task within the diagram (or at least the first student has). This is somewhat different from the instruction these students were given: to use the diagram to keep an overview of the issues under discussion, to display what the students thought were important arguments in order to see what has been discussed so far and what still needs to be discussed.

The students used their chat for managing the task in the diagram. The diagram is used for the benefit of communication and reasoning about content, although this particular one also displays structure quite well. The secondary notation of spacing out different lines of arguments is exploited quite well. Therefore, it is easy to see that these two students have deepened parts of their argument to a large extent[9].

Diagrams that are used as a means of communication more often look like Figure 3. These students used the boxes instead of the comments to put their arguments in. The advantage is that students can immediately see what they are discussing, the disadvantage is that the structure is less clear. When inspecting the diagram in Figure 3 closely, it can be seen that the whole diagram is in fact one deep line of argument, starting on the top left, moving like a snake from right to left, and ending in a conclusion in the middle left. Of course, several subtopics are mentioned in this line of argument, but overall the breadth of the space of debate is restricted to jobs and money, in which side topics such as environment are woven.

[9] It needs to be noted that the analysis of broadening and deepening considers content of an argument. Therefore, breadth and depth based on the structure of an argument needs to be interpreted with caution.

Figure 3. *Another example of discussion through the diagram*

In the second category of diagrams, the diagram is more a reflection of the debate, or a way to structure the debate. The next diagram on industrial change (Figure 4) is not a debate, but an overview in which the dyad tried to structure the diagram with positive arguments placed at the left of the statement/ topic, and negative arguments on the right. The perceived benefits of this kind of diagram are much more related to structure and relations of the argument than to a guide for communication and reasoning. This has led to a diagram that mostly shows broadening, but not deepening. The occurrence of this kind of diagram does not necessarily mean that students have discussed in chat and put the results of their discussion in the diagram. It could mean that they haven't discussed in chat either. For example, the dyad that created the diagram in Figure 4 only used 53 lines of chat, most of them related to task management and social relation. When arguments were discussed in chat, they were discussed in light of creating the diagram. For example:

Rebecca do u think that crime would increase ?? :S
William mayb
Rebecca Ill put that then

The structure of the diagram was also not a topic of discussion in chat, so again it is very difficult to say how this kind of diagram came about. However, the replay function of Drew shows that students started with the box of 'Industrial Change', and then created the other boxes with arrows, to later structure them in order to give the diagram its' final shape.

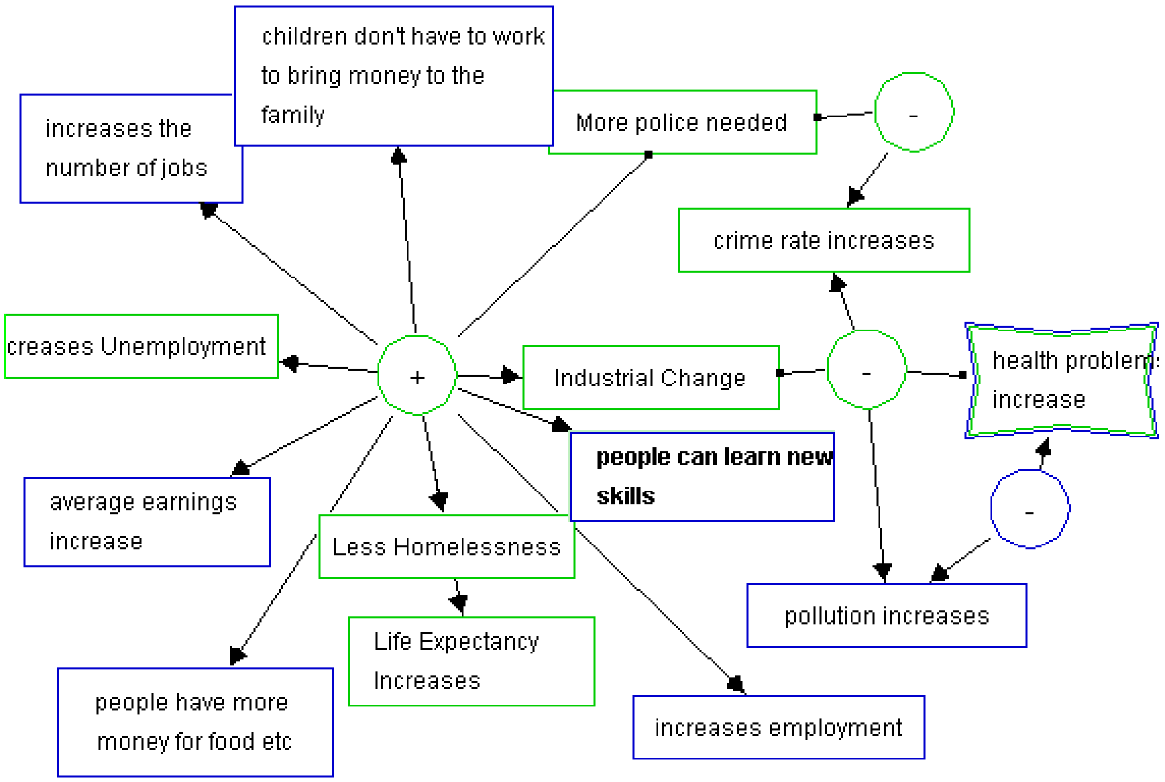


Figure 4. *An example of a diagram to structure the space of debate*

There is a lot of variety in how students reflect the space of debate in this second category. This can be explained with secondary notation. For example, the diagram in Figure 4 has used overall space to put boxes with arguments in favour on the left, and boxes with arguments against on the right. The students who constructed the diagram in Figure 5 put the statement in the middle of the diagram, and put only negative arguments around it. This diagram was made in the study discussed in Chapter 4. These two students were asked to prepare for debate by elaborating upon the standpoint against punishing doctors for medical mistakes. They perceived the task as asking for a diagram that only gives arguments against punishing doctors. Although this is a potentially correct interpretation of the task, I hoped they would also consider the arguments in favour (the opposition) and try to refute these in order to prepare for the subsequent debate. Santos & Santos (1999) argued that students think that raising counterarguments decreases the persuasive power of an argument, which may have been the reason for the appearance of this diagram.

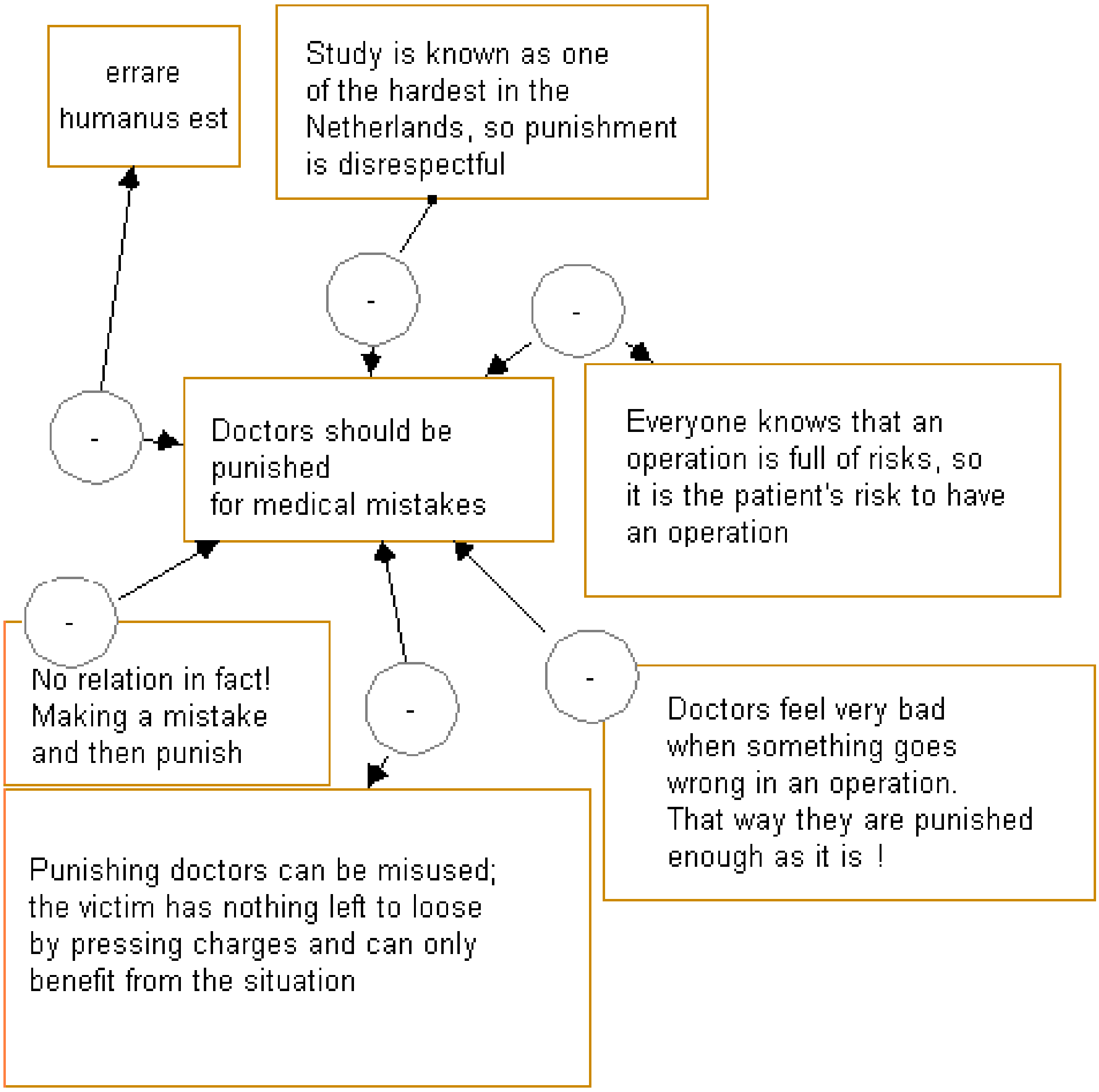


Figure 5. *Another example of a diagram to structure the space of debate*

Is there a clash between communication and structure in a diagram?

The examples given above show that the appearance and benefits of the diagram are dependent on the (perceived) task and on the students who construct them. However, there is no one-to-one relation between tasks, students, and diagrams. The different conditions in the described studies may have created different kinds of reasoning and collaboration, but did not account for the two kinds of diagrams described above. I therefore cannot say: When you want students to use the diagram to transform knowledge, the appearance of the diagram should be like this, the task has to be that, and the benefits will be thus. The relations between the three corners of the diagram are more complex and subtle than that.

What these examples have also shown is that the diagrams students create seem to be either aimed at communication or at structure. There seems to be a incompatibility between the beneficial aspects of structure and relations a diagram can offer and its communicative benefits.

This apparent clash seems to suggest that a diagram cannot adequately capture both, or at least that students focus on one or the other. But can this apparent incompatibility between reasoning in a diagram and structuring the diagram be resolved? I would argue it could, and it should. Students need to be clear and explicit about their reasoning, which means they should combine reasoning with structure. Before I move on, it has to be noted that a total dichotomy is impossible. First, a diagram always has a structure. Content and structure necessarily go together in a diagram. Second, structure is also a means to communicate, and communication has a structure. The structure of a diagram should result from and lead to further communication and reasoning.

The main reason that makes a diagram good for argumentation compared to other representations is the way it can represent argumentative structure and relations. The main reasons to use argumentation in collaboration are mechanisms such as co-construction, transformation of knowledge, and different ways of structuring (e.g., Chinn & Anderson, 1998; O'Donnell, 1999; Leitão, 2001; Reznitskaya et al., 2001). The power of collaborating on an argumentative diagram is that the diagram can be constructed and structured collaboratively. It is not important that the diagram displays one's own opinion, but that the diagram is a collaborative exploration of the space of debate. If students structure their collaborative space of debate, they can both broaden and deepen their space of debate instead of working at only one of these concepts. For example, if they visually distinguish their arguments in favour and their arguments against, they can see whether they have adequately supported their statement. If they organize their diagram in such a way that every topic receives its own argumentative line, they can see how many topics they have discussed. Students need to learn that they can combine structure and communication. For collaborative learning to work, students need to form mutual knowledge and structural relations (Schwartz, 1995). We could try to resolve the apparent incompatibility by starting at each end of the triangle in Figure 1. First, we could change the task to artificially divide the two kinds of diagrams. Although there is no one-to-one relation, it seems that one kind of diagram is better for certain activities than another kind of diagram.

The *discussion* diagrams in the first category are very useful when students are asked to discuss without the diagram being needed for subsequent activities. Using the diagram to express arguments can be seen as an interactive use to convey ideas to a collaborating partner. This kind of use asks for a response in the present time instead of constructing the diagram for later reference, which may make structure less important. Tang (1991) carried out an experiment with small groups of three or four people (face-to-face) who were asked to design a human-machine interface using a collaborative drawing space. He found that especially when students were expressing ideas, the resulting drawings often do not make sense by themselves, but can only be interpreted in the context of the accompanying dialogue. Fay, Garrod, Lee & Oberlander (2003) had two students play a pictionary game several times, in which their drawings became more and more abstract. The students understood each other perfectly, while an outsider could not understand the drawings. Similarly, in an argumentative diagram that is mostly used to communicate, the diagram does not have to be 'readable' for outsiders.

The *structure* diagrams in the second category are useful when students are asked to use the diagram for another activity after discussion, such as debating or writing a text. These diagrams have to be readable for later use. Secondary notation is important in these diagrams. A lot of research has been done on how students read diagrams that are presented to them. For example, Wiegmann et al. (1992) have shown that clustering of related information in a diagram improved encoding and retrieval of information.

Maybe discussion in a diagram is the first step and structuring is the second step, as it is in text. When writing a text one also has to revise and restructure before the text is acceptable. In the conversation mode, the purpose of the diagram can be 'diagramming to learn' (cf. 'arguing to learn' in Chapter 2), in which ideas are constructed. In the structuring mode, as in revising text, students are revising their ideas. This can be a process of knowledge transformation (Bereiter & Scardamalia, 1987). In text this is very hard to do. In computer-based argumentative diagrams restructuring is probably easier, because boxes and relations can be easily rearranged, and complex relations can be shown by simply changing or adding arrows. Whether these diagrams would improve knowledge transformation because of the ease of revision, or whether they would impair knowledge transformation because it is the effort that is put in that makes the transformation happen, is a topic for further investigation. The replay function in Drew (the protocols of the students can be replayed in real-time, step-by-step or fast forward, so the researcher can see what students did during the whole course of their collaboration) revealed that students already make this distinction between communication and structure phase naturally. They mostly start with generating arguments in boxes and using arrows, to later reorganise the boxes (Baker, Quignard, Lund & Séjourné, 2003). In Chapter 6, we explicitly asked students to reorganise their diagram to improve it. The fact that they reorganised is thus not the difference between those diagrams and the diagrams of the other condition or the diagrams in previous studies. Rather, the difference is that they are asked to reorganise using secondary notation principles. Though all dyads organize their diagram in the end, this is often not to an improvement in secondary notation. In short, students need to learn how to use the diagram for communication and for structuring, which brings us to the second angle of the triangle, the students. We could try to change that angle insofar as we have the means to do so. Maybe students do not know what to do, or do not understand why it would be useful to create (structured) argumentative diagrams. Third, we could change the diagram to ease incorporating communicational and structural aspects in the diagram. I will return to these last two points in the sections on educational implications and implications for design.

Students' activities in CABLE with argumentative diagrams

The importance of how students work with the diagrams was already discussed in the previous sections. Here I would like to focus on students' activities throughout the whole task and within different tools in the computer software.

The quality of argumentation

The Rainbow framework in this dissertation was developed to analyse what kinds of functional activities students carried out. I noticed that inside (assignment-related) and outside (unrelated to the assignment) activities alternated during a task, although students were mostly focused on the task. When students had to manage collaborative writing or diagram construction next to chat, task management took up a lot of their time. In general, only about a fifth of students' activities were argumentative. However, this is not unlike results in other research. Students always spend a lot of time on other activities, such as managing the learning task and social interaction, which is essential for their collaboration (e.g., Van Boxtel, 2000; Veerman, 2000).

Students broadened and deepened their space of debate in many different ways. As can be seen in the previous section, some students mostly broadened their space of debate in the diagram, while others mostly deepened it. Also some students mainly used chat to explore their space of debate, while others used the diagram, or both. However, broadening and deepening the space of debate was not done to a large extent. Students used only pseudo-evidence, evidence that does not really back up an argument. It seems to be very hard for students to use genuine evidence. Kuhn (1991) found similar results in her experiments with adults. Although students were not familiar with the topic they discussed, they did receive information sources in all my studies that also contained genuine evidence. Therefore, the fact that students did not give genuine evidence was probably more related to the task (perception) of discussing viewpoints than to their age or lack of information. Students did use more counter-argumentation than expected from other research (e.g., Leitão, 2001; Kuhn, 1991). Nussbaum and Kardash (2005) carried out an experiment in which they asked undergraduate psychology students to write a text. The group that was instructed to pay specific attention to reasoning, counterarguments and rebuttals wrote a text containing much more counterarguments and rebuttals than the texts of students who were only asked to write an argumentative text. They concluded that students are able to use counter-argumentation, but do not spontaneously use it. They also raise the point of students' interpretation of a task. Students may be able to use counter-argumentation, but may believe that it interferes with the power of the argumentative text. In my studies a short introduction on argumentation with explanations of counter-argumentation was given. This may have caused students to consider counter-argumentation more than in other studies.

Unfortunately, students typically took large steps in their reasoning, instead of carefully exploring the space of debate in every direction. Their general reasoning went from cause to consequence, not from premises to conclusions. See Figure 4 for example: "Industrial Change → increases the number of jobs". Or: "Industrial Change → crime rate increases".

Task interpretation is possibly a reason for these findings, but we may also have expected too much from students. The students who participated in our studies are in the top level of secondary school education, but at their age they have just started to use the higher levels of argumentation such as counter-argumentation and evidence to back up arguments (Coirier, Andriessen & Chanquoy, 1999). Still, these students are the ones who will move on to college and university levels, in which argumentative skills are highly valued. Even if they are not very good at broadening and deepening a space of debate yet, they are trying, exploring, exercising, and learning. A column in *Metro* (14-02-2006) argued against the statement that gaming would be bad for children, by stating that a lot is learned from these games, such as collaboration and strategies. In the same way, collaborative argumentation-based learning in our studies can be seen as a preparation for future learning (Schwartz & Martin, 2004).

Perhaps related to these findings, students' activities when working with the tools were diverse. Students used tools in different ways. For example, we have seen students use chat for a thorough discussion of the space of debate, to manage the task of diagram construction or task writing, and also to discuss everything but the task at hand. Similarly the diagram was used for many different purposes, such as: a medium of discussion, as input for further discussion, to tell or copy information, to constitute new information, to transform knowledge, to remember one's own arguments, to structure information, and to give an overview of discussion. These differences in activities cannot only be attributed to conditions. Although a condition in which students were asked to individually create a diagram led to comparison of diagrams, while a condition in which they were asked to collaboratively create a diagram did not, again there was more variation within conditions than between conditions. It is not possible to say that only some of the uses mentioned are correct and others are not. We do not know enough about why individuals or dyads use the tools in different ways yet. It is worth investigating how two students align their activities when constructing a diagram together. This dissertation has painted the picture of how students work with tools, but before we move on to investigating why they do so, we shouldn't decide to restrict students in their tool-use too much, but support them in different uses of the diagram.

Transfer problems

Not only did students use the tools in different ways, they also used different tools. As said before, some students mainly used chat to explore their space of debate, while others used the diagram, or both. While it is no problem in itself that students have their own preferences for some tools over others, a major bottleneck is transfer or translation. We have seen transfer problems from one phase to another, from individual to collaborative work and the other way around, and from one tool to another (from chat to diagram, from diagram to text, from diagram to chat). For example, the Mountains-Valleys-Rising Slopes analyses in Chapter 3 showed that most dyads were either Mountains or Valleys. Only a few of them broadened and deepened their space of debate in chat, and then showed a similar or even better breadth and depth in their collaborative text. The microanalysis in Chapter 4 showed that students sometimes discussed the space of debate to a large extent in chat, to resort to copying information from their individual diagrams when asked to make a collaborative one. Students seem to treat these phases and tools as separate entities. This is bad for learning, since translation has been associated with transforming knowledge (e.g., Ainsworth, Bibby & Wood, 2002; Seufert, 2003). I wonder whether this transfer problem is related to a lack of motivation. Students probably do not realize (or do not care) that their learning may improve if they translate between phases and between tools. The tasks did not incite an overwhelming need for transfer.

From a pedagogical viewpoint, students' transfer problems point to the direction of not artificially dividing (or scripting) tasks rigidly. The dichotomy between communication and structure in an argument could be addressed by asking students to communicate only through chat, and structure their argument through the diagram. However, the transfer problems suggest that students then may treat them as two different assignments, which undermines the positive effects of *dialogic argumentation*. From a theoretical viewpoint, in contrast, it may be interesting to artificially divide argumentative subtasks such as summarizing, countering, concluding, and investigate how students use the given tools in any of these subtasks. Conclusions of these artificial divisions can help us understand why students use tools in certain ways and may help tool design.

Methodological considerations

In this dissertation quantitative and qualitative analyses, and process and product measures were combined to get a grip on collaborative argumentation-based learning with diagrams. The focus, however, was mainly on qualitative process measures. Qualitative processes provide more insight into how and to what extent students collaboratively co-construct knowledge. Qualitative analyses may reveal important processes that can then be analysed in a quantitative way on a larger scale. For instance, the results point to the direction of focusing on transfer.

Product measures received less attention, although performance on tasks after collaboration was investigated. Some effects of the tools have been found, such as a broader and deeper space of debate after computer-supported collaboration than before. More effects of the tools may come with time; when students have worked with the tools for a longer period of time, or with a longer gap between intervention and test of learning (Howe, McWilliam & Cross, 2005). Additionally, the effect may be different than expected. Students may have learned more about collaboration or about working with tools than about argumentative domain knowledge.

A major strength of the studies is the holistic approach in which the collaborative processes were analysed. Instead of looking at chat and diagram in isolation, the two were analysed as part of the same process. This helped me gain insight in how one representation is used as input for the other. It also showed that my initial assumption of the diagram supporting the chat was false. The two are much more intertwined and feed each other, sometimes implicitly (cf. Van Drie & Van Boxtel, 2004; Munneke, Van Amelsvoort & Andriessen, 2003). Both the Rainbow framework and the analyses of Broadening and Deepening the space of debate are able to capture students' activities holistically (see sections below).

Quasi-experimental design

The studies in this dissertation had a quasi-experimental design. Different conditions were compared in a real school setting, in complex tasks that were mostly new to students. Results show effects of the different conditions, but the differences were small. Variety between dyads in a condition was often larger than variety between the different conditions. The differences between conditions may have been too small to expect large differences (G. Salomon, personal communication, July 1, 2004). For example, in Chapter 2 the only difference between conditions when students collaborated was that some dyads could inspect their own text, others their own diagram and still others a given diagram. The similarities between conditions and goals of discussion and text writing were larger than the differences. Moreover, in complex tasks like the ones in my studies, many other aspects could influence processes and products, including experience with collaboration, computers and writing, skills in writing, social skills, task approaches, and personal beliefs. The combination of checking conditions and microanalyses on dyads revealed a complex interplay. If we want to see more effects of conditions in studies like these, the treatments have to be very strong.

Rainbow

The Rainbow framework was collaboratively developed[10] in the SCALE project and applied in most of the studies in this dissertation. Rainbow is a functional analysis to categorise students' utterances when collaborating. Rainbow is not the first instrument developed to categorise utterances. Other researchers have categorised utterances with different purposes in mind (see for example Kuhn, Shaw & Felton, 1997; Van Boxtel, 2000; Van Drie, 2005). The Rainbow framework has three major strengths. First, Rainbow can be used to categorise not only chat utterances, but also collaborative construction of diagrams, writing of text, and usage of other features in the computer environment[11]. For example, clicking the button 'word count' is considered a task management activity, just as chatting about what to do next is. This enables Rainbow to show the whole process of collaboration as an entity, irrespective of the modality students are working in. Second, the Rainbow categories are relatively simple and intuitive. Only seven categories are distinguished. Rainbow has been used by all partners in five different countries in the SCALE project, and also by some researchers outside of the project. Third, the Rainbow framework assigns colours to categories, which enables a quick overview of the process of collaboration.

The Rainbow results in this dissertation have shown that about a fifth of students' activities in CABLE is aimed at argumentative activities, such as exchanging opinions, giving arguments and counterarguments. When students have to write a collaborative text besides chatting together, 60 to 70% of their activities are aimed at managing the task. When a diagram needs to be constructed next to chat, task management is somewhat lower, around 40%. In the different studies of the countries in our SCALE project, we saw that task management activities increase dramatically as soon as students have to carry out an extra task besides chatting.

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[10] The rainbow framework was collaboratively developed by researchers from four different countries: Michael Baker, Jerry Andriessen, Matthieu Quignard, Marije van Amelsvoort, Kristine Lund, Timo Salminen, Lia Litosseliti. See Baker, Andriessen, Lund, Van Amelsvoort & Quignard (2006) for more information.

[11] The Rainbow framework was originally developed to analyse chat activities, but my colleague Lisette Munneke and I changed the framework to include online text writing and diagram construction as well.

The seven categories alternate during the task. Students start and end with some social activity and interaction management, such as exchanging greetings. Argumentative interaction is alternated with social activity, off-task talk, and task management. The Rainbow colours can show this at a glance (unfortunately this dissertation can only show shades of grey in Table 1).

Table 1. *Excerpt of chat discussion analysed with Rainbow*

Name	*Rainbow category*	*Chat*
Will	3	Helloooo
Marlene	3	Hi
Marlene	3	Who are you?
Will	3	Heeeeey ☺
Will	3	Will
Marlene	3	I Marlene!!!!!!
Marlene	2	How ru?
Will	2	good, and you?
Marlene	3	are you
Will	2	yes good!!!
Marlene	5	What is your standpoint?
Will	5	That I didn’t agree with the statement, you?
Marlene	5	So you are against GM?
Will	5	yes certainly
Marlene	5	I was/ am in favour
Marlene	5	Why are you against?
Will	6	Well, see (there it comes ☺), nature has made all organismmms…. soo if we humans start changing that, that is stupid ☺
Will	5	and why are you in favour?
Marlene	5	Yes ok, but there are also many disadvantages
Marlene	3	Uh I mean advantages
Will	3	I thought so

This excerpt shows that Rainbow categories alternate all the time. It also shows that an utterance sometimes has additional meaning. For example, the ‘smileys’ used in the argument given by Will give the utterance not only an argumentative, but also a social meaning. I chose to categorize the argumentative meaning in this message because of its importance in the research. The example reveals that students try to manage their collaborative interaction and their argumentative interaction at the same time.

Broadening and Deepening the space of debate

The concepts of broadening and deepening were introduced in this dissertation to analyse how students explore the space of debate together. The two concepts were first described in the theoretical framework. Broadening the space of debate has to do with the different points of view that can be taken in the issue, or the different subtopics that are distinguishable in the issue, and the arguments that accompany them. Deepening the space of debate has to do with being able to argue about argumentation, seeing the relations between the different views and subtopics, and understanding the more fundamental issues and questions involved.

The analysis of broadening and deepening has undergone some changes in the course of the dissertation. In the first study, different kinds of argumentative moves received numbers to indicate how deep they were. A distinction was made between arguments, examples and explanations, counterarguments and rebuttals, and explicit relations in a hierarchical order. In later studies, I wanted to place more emphasis on the sequence of arguments to indicate depth. Following Kuhn (1991), the labels were changed into claim, supportive and alternative, counter, rebuttal, and evidence. An article on this analysis method is in preparation (Van Amelsvoort & Munneke, 2006).

One of the strengths of broadening and deepening analyses is that they can show the process of exploration. The concepts do not judge the correctness of arguments, nor do they follow logical argumentation, because students are engaged in collaborative explorations of the space of debate (Nonnon, 1996). Rather, the concepts indicate to what extent students incorporate different topics and actors in the debate (broadening) and to what extent they go into these topics and ideas of actors in the debate (deepening). Just like the Rainbow framework, breadth and depth can be used over different modalities and tools, so that the process in chat, diagram, and text is considered one entity. Moreover, breadth and depth of the space of debate can also be used to assess individual ideas of students, so the process can be followed from individual ideas to collaborative discussion and back.

The fact that breadth and depth do not judge the correctness of arguments can also be considered a limitation. It is possible that students broaden and deepen the space of debate with arguments that do not make sense. I chose not to consider the correctness of arguments because arguments that are not logical or correct may still contribute to the learning process. They may help students come to other conclusions for example. Moreover, we are talking about open domains on which multiple 'solutions' exist. However, broadening and deepening would thus not be the best measure of correct information learned (i.e., whether arguments are correctly attributed to certain stakeholders, or whether genetic modification as a concept is correctly understood). Another limitation is that broadening and deepening are not easily distinguished in real-life argumentation. When students deepen an argument they can include new topics, thus also broadening the space of debate.

The next example in Table 2 displays how broadening and deepening of the space of debate was scored during collaboration on one of the cases of Chapter 5 (about sending grains to Ethiopia, where people are starving). This excerpt shows all argumentative content the dyad discussed in both chat and diagram. If we take a closer look, we see that a large part of the chat is concerned with the two students understanding each other and refining their point of view and argumentative knowledge. They discussed what exactly should be send to Ethiopia, seeds or grains, and whether these should be used to cultivate, or to feed the people immediately. The two students reached an agreement that takes a middle view. Many dyads negotiated the space of debate like this couple did, not always talking in strict argumentative terms, but discussing causes and consequences, or refining knowledge. This can make the labels for deepening activities a little awkward. For example, the sentence "Poor farmers will become poorer, rich farmers richer" is not really evidence for "There will be more poverty", but more of a refinement of the statement. Also, students continuously relate different topics, such as famine, money, and consequences for farmers, which makes it difficult to score breadth of the space of debate. However, with a thorough discussion on the analyses beforehand, we managed high interrater reliability.

The diagram is a reflection of what happened in chat in this dyad. Some large parts of the chat are neatly summarised in one box in the diagram. At the start of the chat, Adriana says that "poverty will disappear", but in the diagram she changed this into "more poverty". It is uncertain whether this is a mistake or done on purpose because it better fits the diagram. Note that Adriana constructed the whole diagram alone, so she also put Maria's arguments in the diagram. As a matter of fact, this was something that received a lot of attention in chat towards the end, because Adriana was angry at Maria for not constructing the diagram with her.

Table 2. *Protocol analysed on broadening and deepening the space of debate*

	Medium	Argumentative content	Breadth	Depth
Maria	chat	I am in favour of GMOs in this case		give claim
Maria	chat	you?		ask claim
Adriana	chat	Me too		give claim
Maria	chat	Bad for the economy	affluence-costs/benefits	give alter
Maria	chat	But a bad economy is better than famine	affluence-hunger/food	give rebuttal
Adriana	chat	No, because by means of production and more food poverty will disappear	affluence-division	give rebuttal
Adriana	chat	More jobs because of more farming land when it is treated with gm	affluence-division	give pseudo evidence
Maria	chat	But food, not seeds, so not good for employment	aff-division	give rebuttal
Maria	chat	Farmers don't get money for that little food they did cultivate	aff-division	give pseudo evidence
Adriana	chat	No the land is treated so that it can stand the heat	environment-agriculture	give rebuttal
Adriana	chat	They will get gm-seeds and so on	environment-agriculture	give pseudo evidence
Maria	chat	They get food, not grains	indefinable	give rebuttal
Adriana	chat	They get grains	non-topic	give rebuttal
Adriana	chat	grains can be sown	indefinable	give pseudo evidence
Maria	chat	You won't sow grains if you can feed starving children with it	aff-hunger/food	give rebuttal
Adriana	chat	They have to think about the future, a part for food, a part for future harvests	aff-hunger/food	give rebuttal
Maria	chat	Totally agree!	aff-hunger/food	agreement
Adriana	chat	ok then	aff-hung/food	agreement
Maria	chat	But they won't do that themselves, it has to be a condition	other-conditional	rebuttal
Adriana	chat	That has to be arranged in an agreement then	other-conditional	give pseudo-evidence
Adriana	diagram	Gm grains to Ethiopia		give claim
Adriana	diagram	There will be less famine	aff-hunger/food	give support
Adriana	diagram	There will be more poverty	aff-division	give alternative
Adriana	diagram	Poor farmers will become poorer, rich farmers richer	aff-division	give pseudo-evidence
Adriana	diagram	More employment if a part will be used to cultivate	aff-costs/benefits	give supportive
Maria	chat	Not more employment, but the old	aff-	give counter

		employment	costs/benefits	
Adriana	chat	That was gone (work) because the farmers don't need employees if there is no harvest, so no harvesting, so the employment returns	aff-costs/benefits	give rebuttal
Maria	chat	That is true	aff-costs/benefits	agreement
Adriana	diagram	Poor farmers become poorer and poorer, producers become richer	aff-division	give alter
Adriana	diagram	because of increase in prices	aff-costs/ben	give pseudo evidence
Adriana	diagram	That makes the farmers very dependent on the producers	aff-division	give pseudo evidence

Generalisation of the findings

Doing research in an educational setting is difficult. There are so many variables that a 'clean' comparison is not possible. However, I chose to do research in a real setting, since this is the environment in which CABLE with diagrams is used. A laboratory setting cannot capture the historical and cultural variables in a school setting. Some parts of our studies, such as investigating diagrammatic features, may be done in a laboratory setting first to put it in the classroom later, although the classroom environment could also change the findings from a laboratory study.

Caution is needed in generalising the findings. First, the studies were all carried out in the context of upper secondary education. Second, in the European project we found many similarities between countries, but also major differences. It seems that the school context, the curriculum, and students' expectations account for that (see e.g., Wierstra, Kanselaar & Van der Linden, 1999). Third, the studies were mostly small-scale, carried out in short periods of time. Replications of the studies on a larger scale and for longer periods of time are needed to make stronger conclusions. Fourth, CABLE with diagrams was investigated in two synchronous computer environments, and in dyads. No comparison was made with face-to-face interaction, with larger groups, or with asynchronous communication. On the other hand, argumentative diagrams were used in multiple situations, with multiple tasks and goals, and combined with different additional representations. Although the studies were not directly comparable due to these variations, it does give us insight in the range of situations in which argumentative diagrams can be used, which may help generalisability.

Implications for design

In 1991, Tang already said: "building computer tools for collaborative work requires re-examining the design assumptions that have hitherto been used in building tools for individual use." The Drew software, developed in the SCALE project, is an example of a tool that is especially build for collaborative work. It is designed to support argumentative interaction, for example by allowing students to indicate (dis)agreement with every box and arrow separately. Because it is aimed at argumentative interaction, it also supports structure. For example, arrows can be used to indicate a negative or positive relation between two arguments in boxes. However, a diagram that is specifically designed to support argumentative structure, should make structure much more explicit. This can be done in several ways. For starters, the drawing space could be enlarged, to make benefits such as overview possible. Another way of changing the diagram is using colours for example. The software Reason!Able (Van Gelder, 2002) uses different colours to separate different kinds of boxes, such as claim, argument, and example, which may improve readability and retrieval (Wiegmann et al., 1992).

Another possibility to improve both communicative and structural aspects of the diagram is to structure the dialogic diagram space. In Digalo, a tool developed in the European DUNES project, the diagram space can be structured by using a grid (Overdijk & Van Diggelen, 2006). In experiments done with Digalo, the grid was used to structure the argument in own space and other space, by giving each student in a group of three their own quadrant, with the possibility to work in each other's quadrant as well. This grid could also make broadening and deepening a literal activity, asking students to use horizontal space for breadth and vertical space for depth. It could also be applied to force students to use a separate part of the grid for every stakeholder in the debate.

Diagrams can be designed to focus on specific activities in argumentation-based learning. For example, the studies in this dissertation have shown that students hardly weigh different arguments in a diagram. When they were asked to specify relations between arguments by labelling arrows, contrasting relations were seen more often. Therefore, arrows to create relations should be more explicit. A special category with arrows to contrast topics, arguments, and perspectives could help students relate different aspects in the space of debate.

In future research, I plan to alternate laboratory research into small aspects of diagram construction and use with real-life research in schools. For example, I would like to investigate design characteristics as colour and the separate aspects of secondary notation one by one in the lab, in a collaborative setting. Results of these studies could be implemented in a school-based design for CABLE.

Educational implications

The studies in this dissertation were done in the past five years. I have seen changes in the classroom during these years. At the start, it was still quite unusual for students to work collaboratively on the computer. This is much more normal now. In the last two studies in 2005 in the Netherlands and in the UK, students told me they had made diagrams before. Although they had not used collaborative argumentative diagrams before, they knew what concept maps were and how to make them. Also, teachers seem to be more used to playing a guiding role. However, the classroom is far from 'finished' improving. Despite efforts to change that, there is still a focus on learning products instead of learning processes, both from teachers and students. Students are economical human beings who try to finish their tasks with as little effort as possible. We probably all are, so it is not easy to change our 'laziness'. However, we could try to make challenging, fun tasks that ask for deep processing.

Diagrams could very well be a part of those challenging, fun tasks. They are definitely challenging, asking to structure their argument in collaboration. They can also be more fun. For example, knowledge maps, schematic displays of text similar to argumentative diagrams, have been shown to be more attractive than texts (Pander Maat & Van der Ploeg, 2006). However, we need to reconsider the role of diagrams in the classroom in order to achieve fun and challenging diagrams. Reading and writing text plays a central role in the whole course of the school curriculum. We begin with teaching children how to read and write letters, go to simple words, and end with teaching them how to write essays with different genres. In contrast, teaching students how to construct and read representation hardly receives any attention. Maybe the difficulties in combining communication and structure in a diagram ask for a specific form of diagrammatic reasoning students have to learn. The genre of argumentative diagrams should be part of this teaching of diagrams, because argumentative structure is not systematically instructed and evaluated in the classroom (Chryssafidou & Sharples, 2002). Even when students have to learn to write an argumentative text alone, they have to master structure and form to reflect a dialogue (Dellerman, Coirier & Marchand, 1996). Instruction with and collaborative construction of argumentative diagrams could greatly improve discussion and writing.

Teachers could thus play a bigger role in teaching about representations, and in reflection on discussion with diagrams. In this dissertation, the teachers were not involved in teaching, reflection or in the actual discussions. Although teachers' involvement in discussion is not advisable because their input is perceived as input from an authority that cannot be disputed (Veerman, 2000), they could play a bigger role before and after discussion.

Conclusion

The studies in this dissertation have taught us that argumentative diagrams can be beneficial for collaborative argumentation-based learning, but also that there is a complex interplay between these representations, the task, and the students. The studies have given a more subtle view on how argumentative diagrams can support learning. Diagrams can be used among others as a medium of discussion, as input for further discussion, to tell or copy information, to constitute new information, to transform knowledge, to remember one's own arguments, to structure information, and to give an overview of discussion. Students choose these activities, although not necessarily on purpose, depending on their collaboration and on task perception. Broadening and deepening the space of debate happens through the various tools that are present in the computer environment, such as chat and diagram.

Despite the positive findings of these studies, diagrams (and other tools in the learning environment) could be used more optimally. Students have difficulties weighing different information, structuring the discussion, and backing up information. Secondary notation is an important aspect in the possible support students could get from constructing diagrams, since the diagram's structure is the added value it can bring to a discussion. Collaborative argumentation-based learning is not about formal and logic debate, but about negotiation. Students express knowledge and ideas to explore the space of debate together. However, students need to learn how to combine the beneficial possibilities of collaboration and diagram construction to arrive at an optimal exploration of the space of debate. The diagram's structure could help students in weighing relations they create through arrows, and to back up information by using a claim-backing structure instead of a cause-consequence structure. I do not want to argue that this can be done by teaching them one unique way of constructing a diagram - since I believe there is not such a thing as the best diagram in CABLE - but by helping them understand how certain activities can support certain learning processes in specified tasks.

I wish I had learned how to construct diagrams in school. When I decided to put diagrams at the start of every chapter to show how they could support overview and structure of the chapter, I did not realise it was going to be so difficult to create them! I found it very hard to reason in two-dimensional space, to decide what content of a large chapter to put in a small diagram and what to leave out, and especially to decide what kind of relations to put between the different boxes. Not every relation was argumentative for example. I even decided to make a circle diagram for the last chapter to show a holistic view. Despite, or maybe because of these difficulties, the process of constructing diagrams did help me in understanding the structure of my own chapters, and even led to modifications in the chapters. For me, this was an excellent example of 'practice what you preach'. Before we give students diagrammatic assignments, we should try to make some ourselves. For the reader, I hope the diagrams at the beginning of each chapter worked as an advance organiser, gave an overview of the chapters and aroused curiosity to read on. More generally, I hope this dissertation has not only contributed to better understanding of argumentative diagrams, but also provided a space for further debate.

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Summary

Most questions in life do not have straightforward answers. Think about important societal issues such as: Do we need to build houses here or protect the area? Does euthanasia need to be legalised? There are different sides to each issue, each with their own views, arguments and consequences. A good understanding of these issues asks for a thorough discussion.

People should learn how to discuss difficult questions at secondary school, to help them come to their own view and make well-funded decisions for the future. It's not so much about learning to argue, but using interactive argumentation to learn about certain (societal) issues. Unfortunately, it is very hard for people to discuss an issue, due to problems with argumentation and collaboration. People may therefore need support in discussions.

This dissertation focuses on collaborative argumentation-based learning (CABLE) using computers. Students are each seated at their own computer and discuss an issue in pairs. In the computer learning environment students can chat and create an argumentative diagram together. In these diagrams, argumentation is put in a two-dimensional structure, with boxes for arguments and arrows to relate these arguments.

The aim of the dissertation is to understand how argumentative diagrams can support collaborative argumentation-based learning for secondary school students. It is argued that diagrams may help students to get an overview of discussion, to compare views, or to structure their argument. However, these possible benefits of argumentative diagrams have not yet been validated. We need more insight in how these diagrams can help students discuss, what the diagrams should look like, and when they should be used. In the introduction chapter I describe this background, and explain how the dissertation originated from a European project called SCALE.

In separate chapters four studies are discussed in which collaborative argumentation-based learning has been investigated. In these studies I have (i) compared diagrams to other representations, such as text, (ii) researched the collaborative use of diagrams by pairs of students, and (iii) specified the use of diagrams for learning by asking questions, such as: at what point should diagrams be embedded in a task and what should the diagrams look like? In the description of the chapters these questions will be discussed in more detail.

Chapter 2 describes the theoretical framework of the dissertation. The two most important concepts are introduced: (i) *computer-supported collaborative argumentation-based learning*, and (ii) representations, especially *argumentative diagrams*. The first concept is discussed one by one. I start with a general description of learning and knowledge to explain that the studies are embedded in the general theory of constructivism. Collaborative learning naturally evolves from the idea that knowledge is situated in a social and historical context. Moreover, collaboration stimulates activities that bring about learning processes. Then I move on to argumentation, beneficial aspects of argumentation for learning, and learning argumentative knowledge. Argumentation is an important aspect of collaborative learning because one gets to know different views and arguments and because you have to reason together to reach a conclusion. By means of discussion, students are to explore the 'space of debate' of an issue. The space of debate is described as all views, arguments, decisions, facts, emotions, and consequences of an issue. It does not have clear boundaries. Arguments and opinions can change, new arguments can arise, and old arguments may lose their relevance for the issue. The space of debate is created by a community of stakeholders involved in the domain. Students explore the space of debate by broadening and deepening it. Broadening has to do with the different viewpoints that can be taken in the issue by different stakeholders, the subtopics that are distinguishable in the issue and the arguments that accompany them. Deepening the space of debate has to do with being able to argue about argumentation, seeing the relations between the different views and subtopics, and understanding the more fundamental issues and questions involved. Although students can learn a lot from collaborative argumentation-based learning, it has proven to be difficult. Students have problems with certain aspects of argumentation, such as counter-argumentation, backing up arguments with evidence, and relating and weighing different arguments. Also, social factors come into play that may hinder discussion, such as fear of losing face.

In the remainder of the chapter computer-support is suggested to help students overcome these problems. For example, when students discuss through chat, social factors such as status are less apparent than in face-to-face discussion. Another advantage of using computers in collaborative learning is the fact that students can be supported with representations, such as argumentative diagrams. The second important concept of the theoretical framework. One possible benefit of diagrammatic representations as proposed in literature is argumentative structure. However, the literature also elicits questions. For example, positive effects of diagrams for learning have not always been found. Also most diagrams have been researched in closed tasks instead of open tasks, have been presented to students instead of constructed by them, and have been used individually instead of collaboratively. This dissertation aims at a more precise understanding of when and how argumentative diagrams can be beneficial for collaborative argumentation-based learning. The general research question given in Chapter 2 is: How does the construction of argumentative diagrams in a synchronous computer environment by students in pre-university education affect their collaborative argumentation-based learning?

The third chapter investigates the conditions under which diagrammatic representations support collaborative argumentation-based learning in a computer-environment. In the study diagrammatic graphical support is compared to textual linear support. Also, the effect on learning processes of a diagram made by students is compared to the effect of a diagram made by the researcher based on a text made by the students. A third topic of research was the way students actually worked with the representations.

Thirty dyads of 15-18 year old students participated in a writing task on genetically modified organisms (GMOs) consisting of three phases. Students prepared by reading information about GMOs individually and then representing their opinion in either text or diagram. Then they discussed the topic and wrote a text in dyads. They consolidated their knowledge by revising their individual representation. There were three conditions during the collaboration phase: students could inspect either (i) the individual texts they wrote, (ii) the individual diagrams they constructed, or (iii) diagrams that were constructed for them based on the texts they wrote.

Results showed that students who had constructed a diagram themselves explored the topic more than students in the other conditions. They deepened their collaborative text more than students in the other two conditions. For broadening the space of debate, an almost significant effect was found in both chat and collaborative writing. Their individual diagrams after discussion were not broader and deeper than the texts of the students in the other conditions, but they improved more compared to before discussion. Differences were also found in the way students collaborate. I distinguish between three kinds of collaborating dyads: Mountains, Valleys and Rising Slopes. Mountains broaden and deepen their space of debate mainly in chat, but not in collaborative writing. For Valleys, the opposite is true. Rising Slopes broaden and deepen their space of debate both in chat and in writing. Dyads also differ in the way they used their individual representations.

Dyads who engaged in deep discussion used their representations as a basis for knowledge construction. In contrast, dyads that engaged in a shallow discussion used their representations solely to copy information to their collaborative text. I conclude that diagrammatic representations can improve collaborative learning, but only when they are used in a co-constructive way.

Chapter 4 reports on two studies on the context in which computers and representations are used. Much research in the field of computer-supported collaborative learning seems to alternate between enthusiasm about newly developed techniques, and disappointment about the effect of these techniques in the schoolcontext. New techniques do not automatically produce learning, but should be embedded in a broader context. The study in Chapter 4 explored the use of our newly developed computer environment (DREW) tool for the first time. Different aspects of the context have been researched. The first aspect is how computer-based tools should be embedded in the task, related to the nature of the tools, construction versus inspection of tools, goals, and relations between tools. The second aspect is the instruction students receive regarding viewpoints and kind of debate. Third, the context includes how students make meaning together when they work with tools in a specific situation. Thirty-six secondary school students in two separate studies performed a collaborative argumentation-based learning task in which chat and diagram were used to interact. The diagram was embedded in the task in different ways, for example to reflect a student's individual opinion, to discuss or debate a topic together, or to to reflect what was learned from discussion. Dyads either elaborated one viewpoint or debated opposing viewpoints.

All students were found to broaden and deepen their discussion in the Drew-environment. Debating opposing viewpoints led to a higher argumentative interaction than elaborating one viewpoint. However, there was a huge variety in how students worked with the tools. Therefore, a microanalysis on 8 students in 4 dyads was done to investigate the flow of discussion in the different tools in the environment. The extent to which students collaborated effectively proved to be even more important for learning than the general pedagogic design. The relation between chat and diagram was problematic for students. Tools do not make a difference on their own. One of the key issues appears to be the extent to which students collaborate effectively, that is, discussing the topic in length in chat and putting shared ideas in the diagram, instead of dividing tasks. Translation between representations proved to be a problem for students. The results suggest that students need to learn how to translate between chat and diagram for collaborative argumentation-based learning to be more effective.

The previous studies have shown that there is a lot of variety in how dyads work with the tools. They have also shown problems with argumentation and diagram-construction. Chapter 5 focuses on how the construction of an argumentative diagram can support establishing structure and relations in the topic under discussion. Argumentation is, like diagrams, not linear, and students could benefit from structuring their argument to understand how different issues are related. A diagram can highlight communication and argument structure. Forty-four students performed two collaborative argumentation-based learning tasks in which they constructed a diagram in dyads. Students focused on structure and relations by either labelling the arguments in boxes with argumentative words, such as argument in favour or argument against, or by labelling the arrows in the diagram with more causal words, such as but and because. Results showed no overall differences between the two conditions in the extent to which they broadened and deepened the space of debate. However, the dyads who were asked to label arrows created bigger diagrams with more – and more correctly used - labels. More importantly, students who labelled the arrows made many more relations that indicate a contrast than students who labelled the boxes. This means they contrasted different topics in the debate more. Students who created more contrast relations in the diagram scored higher on the posttest about argumentative knowledge on the topic under discussion.

More in general, the extent to which students explored the space of debate was disappointing. Most argumentative activities can be described as ‘minimal argumentation’, a sequence of only one or two moves made by one person. ‘Elaborate argumentation’, consisting of more than four argumentative moves in which students negotiate a topic by using supports, counters, rebuttals and/ or evidence, was only found 29 times in 40 protocols. Also, almost 50% of all relations students create in a diagram go from standpoint to argument. This means the diagram has a shallow appearance.

I conclude that diagrams can be designed to help students focus on argumentative moves that may be important for learning, such as contrasting and weighing arguments. However, we need to give students the opportunity to improve their diagram readership and production skills in order to use diagrams to their full potential.

The study described in Chapter 6 was carried out in the United Kingdom instead of in the Netherlands. It focuses on improving diagram production skills by means of secondary notation. Secondary notation is related to the appearance of a diagram. Primary notation is described as the formal aspects that define a representation, in this case the boxes and arrows of a diagram. Secondary notation can convey extra meaning outside of the formal definition, for example by means of layout, clustering and summarisation. Good and bad diagrams can be distinguished based on their secondary notation: while both diagrams display the primary notation of boxes with arguments and arrows to relate them, a good diagram also uses secondary notation to clarify information, structure and relationships. I wanted to find out whether a short intervention on secondary notation could improve students' diagrams. A subsidiary question was whether the improved diagrams would lead to better individual texts. Seven dyads of secondary school students discussed the topic of Industrial Change, using chat and diagram. Afterwards, they were asked to individually write a text on Industrial Change. Five other dyads were asked the same thing. However, they received an intervention on secondary notation after making the diagram and then were asked to improve their diagram based on the guidelines for secondary notation. Possibly due to the small amount of dyads, no significant differences were found between the conditions. However, the results were in the right direction. Moreover, experts consistently rated the diagrams created after intervention as better than the other diagrams. Students who received the intervention used a higher proportion of their diagram for the individual text than students who did not focus on secondary notation, but experts did not rate the texts as qualitatively better. The results suggest that secondary notation is something that is relatively easy and quick to learn, although not all kinds of secondary notation were as easy to learn. Secondary notation improves the diagram, and seems to improve the translation between diagram and text.

In the seventh chapter the main results of the research are described, and general conclusions are drawn. Other subjects in the chapter are research limitations, methodological considerations, future directions, implications for design, and implications for educational practice.

The results of the studies can be placed in three categories that intertwine: (i) results on the comparison between different representations, (ii) students' collaborative use of these representations, and (iii) specification of argumentative diagrams for learning.

Although this does not do justice to the nuances of the findings, the results generally imply that argumentative diagrams in collaborative argumentation-based learning work, but they could work better. The space of debate is broadened and deepened by students in both chat and diagram. Constructing diagrams seem to be better for discussion than writing texts or receiving diagrams. Diagrams can be used for example to ask students to think about their viewpoint beforehand, to have a discussion or to structure the result of a discussion. However, diagrams could work better than they do now. This leads me to zoom in on the benefits of argumentative diagrams, and to compare the theoretical and practical support argumentative diagrams offer to get more grip on how diagrams work. I also zoom in on the students, how they work with the diagrams, and how we can improve students' activities in argumentative diagrams.

An argumentative diagram is a very *texty* diagram. This limits the affordances normally attributed to diagrams. Moreover, there is a complex interplay between the diagrams, the task, and the students. I illustrate this interplay with an overview of different diagrams that were found in the studies. Roughly, two kinds of diagrams can be distinguished: Diagrams that are used to communicate, and diagrams that are used to structure the debate. The two diagrams seem to be incompatible for students; they are either aimed at reasoning through the diagram, or at structuring argument. I argue that the two should be combined. Of course a diagram always has a structure, structure is also a way to communicate, and communication has a structure. However, students should be more clear and explicit about their reasoning in a diagram, which means they should combine reasoning with structure. The power of collaborating on an argumentative diagram is the combination of representing argumentative structure and relations with collaborative learning mechanisms such as co-construction and transformation of knowledge. Solving the apparent incompatibility of communication and structure in a diagram can involve dividing communication and structure tasks, or helping students learn a special form of diagrammatic reasoning.

In general, there is a problem of transfer or translation between different representations and different phases in a task. Many dyads seem to treat representations and phases as separate activities. For example, they chat at length about a topic, but do not use their chat discussion to create a diagram. From a pedagogical viewpoint, this points to the direction of not artificially dividing tasks. From a theoretical viewpoint however, it may be interesting to divide argumentative subtasks such as summarising, countering, and concluding to investigate how students use the given tools in any of these subtasks. Conclusions of these artificial divisions can help us understand why students use tools in certain ways and may help tool design.

A strength of the research in this dissertation is the holistic approach in which the collaborative processes were analysed. The methods of analyses used in the dissertation analyse the process of collaboration in representations and phases as a whole, helping us to gain insight in how one representation is used as input for the other for example. The quasi-experimental design may have caused some problems. The studies were all done in schools, using conditions to create variety. However, variety between dyads in a condition was often larger than variety between the different conditions. This could be due to many other variables in the school setting not taken into account, such as overall grades and friendships between students, but also to the fact that the differences between conditions may have been too small to detect variety.

Future research could aim at investigating why dyads all work so differently at a task. I have specified different uses of diagrams, such as diagrams as a medium of discussion, as input for further discussion, to tell or copy information, to constitute new information, to transform knowledge, to structure information, and so on. It would be useful to investigate why exactly students choose which activity, depending on collaboration and task perception. How do students align their activities in constructing an argumentative diagram? Other valuable directions for research include investigating transfer problems, and investigating the concept of secondary notation further, to help students construct diagrams in an optimal way. I do not want to imply there is only one right kind of creating an argumentative diagram we should teach students. However, students could learn how to reason with argumentative diagrams to have a broad and deep space of debate.

Samenvatting (Summary in Dutch)

Op vele vragen is geen pasklaar antwoord te geven. Denk aan maatschappelijk belangrijke kwesties als: moeten we hier bouwen of de natuur beschermen? Moet euthanasie gelegaliseerd worden? Elke kwestie heeft verschillende kanten met eigen meningen, argumenten en consequenties. Discussie is een goede manier om zulke kwesties te leren begrijpen.

Mensen zouden op de middelbare school al moeten worden voorbereid op het samen discussiëren over moeilijke kwesties, zodat ze hun eigen mening kunnen vormen en gefundeerde beslissingen kunnen nemen voor de toekomst. Het gaat hierbij niet zozeer om het leren argumenteren, maar om het gebruiken van interactieve argumentatie om te leren over hoe bepaalde (maatschappelijke) kwesties in elkaar zitten. Helaas vinden mensen discussiëren vaak erg moeilijk, onder andere vanwege problemen met argumenteren en samenwerken. Mensen hebben daarom ondersteuning nodig bij discussies.

Dit proefschrift gaat over samenwerkend leren door middel van argumenteren (CABLE; Collaborative Argumentation-Based LEearning) via computers. Leerlingen zitten ieder aan een eigen computer en discussiëren in tweetallen over een open onderwerp, zoals genetische modificatie. In de computer-leeromgeving kunnen leerlingen chatten en samen een argumentatief diagram maken. Argumentatie wordt in deze diagrammen in een tweedimensionale structuur gezet, met blokjes voor de argumenten en pijlen om de relatie tussen de argumenten aan te geven.

Het doel van het proefschrift is te begrijpen hoe argumentatieve diagrammen het samenwerkend leren door argumenteren van middelbare scholieren kunnen ondersteunen. Leerlingen zouden door middel van diagrammen een overzicht kunnen krijgen over hun discussie, standpunten kunnen vergelijken, of meer structuur kunnen aanbrengen in hun discussie. De mogelijke voordelen van diagrammen zijn echter nog niet gevalideerd. Meer inzicht is nodig in hoe diagrammen leerlingen kunnen helpen in hun discussie, hoe de diagrammen eruit zouden moeten zien en wanneer diagrammen gebruikt zouden moeten worden. In het inleidend hoofdstuk beschrijf ik deze achtergrond en vertel hoe het proefschrift deels is voortgekomen uit het Europese SCALE project.

In afzonderlijke hoofdstukken worden vier studies beschreven waarin samenwerkend leren door argumenteren met diagrammen onderzocht is. In de studies heb ik (i) diagrammen vergeleken met andere representaties zoals teksten,

(ii) het gezamenlijk gebruik van diagrammen door paren leerlingen onderzocht en (iii) het gebruik van diagrammen voor leren gespecificeerd door vragen te stellen als: wanneer moeten diagrammen in de taak worden ingezet en hoe moeten ze er dan uitzien? In de beschrijving van de hoofdstukken zullen deze vragen uitgebreider aan bod komen.

Hoofdstuk 2 beschrijft het theoretisch kader van het proefschrift. De twee belangrijkste concepten worden geïntroduceerd: (i) *computerondersteund samenwerkend leren door argumenteren* en (ii) representaties, in het bijzonder *argumentatieve diagrammen*. Het eerste concept wordt per element besproken. Ik begin met een algemene beschrijving van leren en kennis, waarmee uitgelegd wordt dat de studies in het proefschrift vanuit een constructivistisch gedachtegoed zijn ontworpen. Samenwerkend leren komt voort uit het idee dat kennis gesitueerd is in een sociale en historische context. Bovendien stimuleert samenwerken activiteiten die leerprocessen bevorderen. Hierna bespreek ik argumentatie, de voordelen van argumenteren voor het leerproces en het leren van argumentatieve kennis. Argumentatie is een belangrijke vorm van samenwerken, omdat je hierbij verschillende meningen en argumenten leert kennen en samen moet redeneren om tot een bepaalde oplossing te komen. Door middel van discussie exploreren leerlingen samen de 'debatruimte' van een vraagstuk. De debatruimte wordt omschreven als alle meningen, argumenten, besluiten, feiten, emoties en consequenties die met een bepaalde kwestie te maken hebben. De debatruimte heeft geen duidelijke grenzen. Meningen kunnen veranderen, er kunnen nieuwe argumenten gebruikt worden en oude argumenten kunnen hun relevantie voor het vraagstuk verliezen. De debatruimte wordt gevormd door een gemeenschap van belanghebbenden of 'stakeholders' die met het vraagstuk te maken hebben. Leerlingen exploreren de debatruimte door deze te verbreden en verdiepen. Verbreden heeft te maken met de verschillende standpunten en bijbehorende argumenten die kunnen worden ingenomen door de belanghebbenden, en de onderwerpen die te onderscheiden zijn in het vraagstuk. Verdiepen van de debatruimte heeft te maken met dieper ingaan op argumenten, het zien van relaties tussen verschillende standpunten en onderwerpen en het begrijpen van de meer fundamentele punten en vragen in het debat. Hoewel leerlingen veel kunnen leren van samenwerkend leren door argumenteren is uit onderzoek gebleken dat het voor hen soms moeilijk is. Leerlingen hebben problemen met bepaalde aspecten van argumenteren, zoals tegenargumenten geven, argumenten onderbouwen met bewijs en relateren en afwegen van verschillende argumenten. Sociale factoren, zoals angst voor gezichtsverlies, kunnen de discussie ook belemmeren.

Het hoofdstuk gaat verder in op hoe een computer leerlingen ondersteuning zou kunnen bieden bij het oplossen van deze problemen. Wanneer leerlingen bijvoorbeeld kunnen discussiëren via chat zijn sociale factoren als status minder duidelijk aanwezig dan wanneer ze face-to-face discussiëren. Een ander voordeel van het gebruik van computers voor samenwerkend leren is de mogelijkheid leerlingen te ondersteunen met representaties zoals argumentatieve diagrammen, het tweede belangrijke concept van het theoretisch kader. Een mogelijk voordeel van diagrammen zoals beschreven in de onderzoeksliteratuur is bijvoorbeeld argumentatieve structuur. De literatuur roept echter ook vragen op. Er zijn bijvoorbeeld niet altijd positieve effecten van diagrammen op leren gevonden. Ook is het meeste onderzoek naar diagrammen gedaan in gesloten taken in plaats van open taken, met gepresenteerde diagrammen in plaats van door de leerlingen zelfgemaakte diagrammen, en individueel door de leerlingen gebruikt in plaats van samen. Met dit proefschrift wil ik een bijdrage leveren aan een preciezer begrip van hoe en wanneer argumentatieve diagrammen goed kunnen zijn voor samenwerkend leren door argumenteren. De algemene onderzoeksvraag zoals beschreven in Hoofdstuk 2 is: Hoe beïnvloedt het construeren van argumentatieve diagrammen in een synchrone computeromgeving samenwerkend leren door argumenteren bij leerlingen van de hoogste klassen HAVO en VWO?

In het derde hoofdstuk worden de condities onderzocht waaronder representaties samenwerkend leren door argumenteren via de computer ondersteunen. In de studie wordt grafische ondersteuning van een diagram vergeleken met lineaire ondersteuning van een tekst. Daarnaast wordt het effect van een door de leerlingen gemaakt diagram op het leerproces vergeleken met een diagram dat door de onderzoeker gemaakt is op basis van een door leerlingen gemaakte tekst. Er wordt niet alleen gekeken naar de invloed van de representaties op het leerproces, maar ook naar hoe leerlingen met de representaties in de taak omgaan.

Dertig paren leerlingen, 15 tot 18 jaar oud, namen deel aan een driedelige schrijftaak over genetische modificatie via de computer. De leerlingen bereidden zich voor door individueel informatie te lezen over genetische modificatie en daarna hun mening te verwoorden in een tekst of diagram. Daarna discussieerden ze over het onderwerp in tweetallen en schreven samen een argumentatieve tekst. Tenslotte reviseerden ze hun zelfgemaakte individuele tekst of diagram. Er waren drie condities: leerlingen konden tijdens hun samenwerking (i) hun eigen tekst en die van hun partner bekijken (ii) hun eigen diagram en dat van hun partner bekijken, of (iii) twee diagrammen bekijken die door de onderzoeker gemaakt waren van hun eigen individuele teksten.

De resultaten laten zien dat leerlingen die zelf een diagram hadden gemaakt en bekeken het onderwerp meer exploreerden dan de leerlingen in de andere twee condities. Zij diepten het onderwerp meer uit in hun gezamenlijke tekst en verbreedden het bijna significant meer in chat en gezamenlijke tekst. Hun individuele diagrammen na discussie waren niet breder en dieper dan de teksten in de andere condities, maar vergeleken met de diagrammen voorafgaande aan de discussie verbeterden zij het meest. Verschillen werden ook gevonden in de manier waarop leerlingen samenwerken en de representaties gebruiken. Ik maak een onderscheid tussen drie soorten samenwerkende tweetallen: Bergen, Dalen en Hellingen. Bergen verbreden en verdiepen hun debatruimte voornamelijk in chat, maar niet in hun gezamenlijke tekst. Voor Dalen geldt het omgekeerde. Hellingen verbreden en verdiepen hun debatruimte zowel in chat als in hun gezamenlijke tekst. Paren die een uitgebreide discussie voerden gebruikten hun representaties als basis voor kennisconstructie. Paren die maar weinig discussieerden, gebruikten hun representaties enkel om informatie te kopiëren naar hun gezamenlijke tekst. Ik concludeer dat diagrammatische representaties samenwerkend leren kunnen bevorderen, maar alleen wanneer leerlingen ze op een co-constructieve wijze gebruiken.

Hoofdstuk 4 beschrijft twee studies naar de context waarin computers en representaties gebruikt worden. Veel onderzoek in het veld van computerondersteund samenwerkend leren lijkt heen en weer geslingerd te worden tussen enthousiasme over nieuwe technieken en teleurstelling over het effect van deze technieken in de schoolcontext. Dit soort nieuwe technieken zorgt niet vanzelf voor positieve leerprocessen of leereffecten, maar moet worden ingebed in een bredere context. In de studie uit hoofdstuk 4 werd het gebruik van onze nieuwe computer-leeromgeving (DREW) voor het eerst geëvalueerd. Een drietal aspecten van de context is onderzocht. Het eerste aspect is hoe computer'tools' als chat en diagram kunnen worden ingepast in een taak, afhankelijk van de eigenschappen van de tools, constructie versus inspectie van tools, doelen, en relaties tussen tools. Het tweede aspect gaat om de instructie die leerlingen krijgen over standpunten die ze kunnen of moeten innemen. Het derde aspect in de bredere context gaat om de vraag hoe leerlingen samen betekenis creëren wanneer zij werken met de tools in een bepaalde situatie. In twee aparte studies voerden zesendertig middelbare scholieren in tweetallen een discussieleertaak uit met chat en diagram. Het diagram werd op verschillende manieren ingezet, bijvoorbeeld om individueel een mening te geven, om samen een discussie of debat te voeren, om samen een conclusie weer te geven, of om weer te geven wat er van de taak geleerd was. Paren werkten ofwel samen één standpunt uit of ze debatteerden over twee tegenovergestelde standpunten.

Alle leerlingen verbreedden en verdiepten hun discussie in de Drew-omgeving. Het debatteren over tegenovergestelde standpunten leidde tot meer argumentatieve interactie dan het samen uitwerken van een standpunt. Er was echter grote variatie in hoe studenten met de tools werkten. Om meer inzicht te krijgen in het verloop van de discussie in de verschillende tools is een microanalyse uitgevoerd op 8 leerlingen in 4 paren. Hieruit bleek dat de manier waarop leerlingen met elkaar en de tools interacteren nog belangrijker is dan de manier waarop de tool is ingebed in de taak. Het gebruik van tools zorgt niet automatisch voor een verbetering van leren. Een van de sleutelbegrippen blijkt de mate waarin leerlingen effectief samenwerken. Effectieve samenwerking betekent dat leerlingen het onderwerp intensief bediscussiëren in chat en gedeelde ideeën in het diagram zetten in plaats van taken verdelen. De relatie tussen chat en diagram bleek echter problematisch voor de leerlingen. De resultaten suggereren dat leerlingen zouden moeten leren hoe ze kunnen vertalen tussen chat en diagram om samenwerkend argumentatief leren effectiever te laten zijn.

De voorgaande studies hebben laten zien dat er veel variatie is in hoe leerlingen werken met de computertools. Ze hebben ook problemen blootgelegd met betrekking tot argumentatie en diagramconstructie. Hoofdstuk 5 focust op de vraag hoe de constructie van een argumentatief diagram kan helpen structuur en relaties aan te brengen in het onderwerp waarover gediscussieerd wordt. Argumentatie is, net als een diagram, niet lineair en leerlingen kunnen door het structureren van hun argument leren begrijpen hoe verschillende onderwerpen met elkaar verweven zijn. Vierenveertig leerlingen voerden twee argumentatieve leertaken uit waarin ze in tweetallen een diagram maakten. De nadruk lag op structuur en relaties door leerlingen te vragen de argumentatieve inhoud van hun blokjes te labelen met argumentatieve woorden zoals argument voor en argument tegen, of door ze te vragen de pijlen tussen argumentatieve blokjes te labelen met meer causale woorden, zoals maar en omdat. Resultaten laten geen algemene verschillen zien tussen de twee condities in de mate waarin leerlingen hun debatruimte verbreedden en verdiepten. De paren die de pijlen moesten labelen maakten wel grotere diagrammen en gebruikten meer - en meer correcte - labels. Bovendien bleken leerlingen die de pijlen labelden veel meer relaties te leggen die een contrast aangaven dan de leerlingen die de blokjes labelden. Dit betekent dat zij verschillende onderwerpen in het debat met elkaar vergeleken. Leerlingen die meer contrast-relaties legden in het diagram scoorden ook hoger op de posttest waarin argumentatieve kennis over het onderwerp gemeten werd.

Meer in het algemeen was de mate waarin leerlingen de debatruimte exploreerden echter matig te noemen. Het grootste deel van de argumentatieve activiteiten kunnen worden bestempeld als ‘minimale argumentatie’, een sequentie van één of twee argumentatieve uitingen gedaan door slechts een leerling. ‘Uitgebreide argumentatie’, een sequentie bestaande uit meer dan vier argumentatieve uitingen waarin twee leerlingen een onderwerp bediscussiëren via onderbouwingen, tegenargumenten, weerleggingen en bewijsvoeringen, werd maar 29 keer gevonden in 40 protocollen. Ook is bijna 50% van alle relaties die leerlingen in het diagram legden een relatie van standpunt naar argument. Dit betekent dat de diagrammen oppervlakkig waren.

Ik concludeer dat diagrammen zo ontworpen kunnen worden dat ze leerlingen bijvoorbeeld helpen te focussen op argumentatieve uitingen die belangrijk zijn voor leren, zoals het afwegen van argumenten en onderwerpen. Daarvoor moeten we leerlingen echter wel de kans geven hun leesvaardigheid en schrijfvaardigheid met betrekking tot diagrammen te verbeteren, zodat ze diagrammen optimaal kunnen gebruiken.

De studie die in Hoofdstuk 6 beschreven wordt, is uitgevoerd in Groot-Brittannië. De studie gaat over het optimaliseren van diagrammen door middel van secundaire notatie. Secundaire notatie heeft te maken met hoe een diagram eruit ziet. Primaire notatie wordt beschreven als de formele aspecten waaruit een representatie bestaat, in dit geval zijn dat de blokjes en pijlen van het diagram. Secundaire notatie kan extra informatie overbrengen buiten de formele aspecten, via bijvoorbeeld lay-out, clusteren en samenvatten. Goede en slechte diagrammen kunnen onderscheiden worden op basis van hun secundaire notatie: ze hebben dezelfde primaire notatie (argumenten in blokjes en relaties tussen argumenten via pijlen), maar een goed diagram maakt daarnaast gebruik van secundaire notatie om informatie, structuur en relaties duidelijker aan te geven. Ik wilde weten of een korte interventie gericht op secundaire notatie de diagrammen van studenten kan verbeteren (de diagrammatische schrijfvaardigheid van leerlingen verbeteren). Een onderliggende vraag was of een verbeterd diagram zou leiden tot betere argumentatieve teksten. Zeven paren middelbare scholieren bediscussieerden het onderwerp “Industriële verandering” via chat en diagram. Daarna werd hen gevraagd individueel een tekst te schrijven over industriële verandering. Vijf andere paren moesten hetzelfde doen, maar kregen een interventie over secundaire notatie na hun discussie, waarna ze hun diagram moesten verbeteren door het gebruiken van secundaire notatie. Er werden geen significante verschillen gevonden tussen de condities, waarschijnlijk vanwege het kleine aantal paren. De resultaten waren wel in de verwachte richting. Bovendien beoordeelden experts de diagrammen na interventie consequent als beter dan de andere diagrammen. De studenten die de interventie hadden gehad gebruikten een groter deel van het diagram in hun individuele tekst dan de studenten die geen interventie hadden gehad, maar experts gaven geen beter oordeel over de kwaliteit van hun teksten. De resultaten suggereren dat secundaire notatie relatief makkelijk en snel te leren is, hoewel niet alle soorten secundaire notatie even gemakkelijk te leren zijn. Secundaire notatie verbetert het diagram en lijkt de vertaling van diagram naar tekst te verbeteren.

In het zevende hoofdstuk worden de belangrijkste resultaten van de studies beschreven en worden algemene conclusies getrokken. Andere onderwerpen van het hoofdstuk zijn beperkingen van het onderzoek, methodologische overwegingen, toekomstige onderzoeksmogelijkheden, implicaties voor toolontwerp en de schoolpraktijk.

De resultaten van de studies kunnen in drie gerelateerde categorieën geplaatst worden: (i) resultaten over de vergelijking tussen verschillende soorten representaties, (ii) het gezamenlijke gebruik van deze representaties door paren leerlingen, en (iii) specificaties van argumentatieve diagrammen voor leren.

Hoewel dit geen recht doet aan de nuances van mijn bevindingen, kun je in het algemeen zeggen dat de resultaten laten zien dat diagrammen in samenwerkend leren door argumenteren wel werken, maar dat ze beter zouden kunnen werken. De debatruimte wordt door leerlingen samen verbreed en verdiept in zowel hun discussie als in hun diagram. Het maken van diagrammen lijkt beter te werken dan het schrijven van tekst of het krijgen van een diagram. Diagrammen kunnen gebruikt worden om leerlingen vooraf te laten nadenken over hun mening over een bepaald probleem, om hun discussie in te voeren of het resultaat van hun discussie in te structureren. Toch zouden diagrammen beter kunnen werken dan ze nu doen. Daarom ga ik dieper in op de voordelen van argumentatieve diagrammen en vergelijk ik de ondersteuning die argumentatieve diagrammen in theorie en praktijk kunnen bieden om meer grip te krijgen op hoe ze werken. Ook ga ik dieper in op hoe studenten omgaan met de diagrammen, en hoe de activiteiten die studenten uitvoeren in het gebruik van diagrammen verbeterd kunnen worden.

Een argumentatief diagram is nogal 'tekstueel'. Dit beperkt de voordelen die normaal aan diagrammen worden toegeschreven. Bovendien is er een complex samenspel tussen de diagrammen, de taak en de studenten. Ik illustreer dit samenspel aan de hand van verschillende diagrammen uit de studies. Er kunnen ruwweg twee soorten diagrammen worden onderscheiden: diagrammen die worden gebruikt om te communiceren en diagrammen die gebruikt worden om het debat te structureren. Het lijkt of deze twee soorten diagrammen voor studenten onverenigbaar zijn. Studenten zijn ofwel gericht op redeneren via het diagram ofwel op het structureren van de argumenten. Deze twee zouden echter gecombineerd moeten worden. Natuurlijk heeft een diagram altijd een bepaalde structuur, is structuur ook een middel om te communiceren en heeft communicatie een structuur. Studenten moeten echter duidelijker en explicieter zijn in hun redeneringen in het diagram, wat betekent dat zij communicatie en structuur moeten combineren. De kracht van samenwerken in een diagram is de combinatie van representatie van argumentatieve structuur en samenwerkend leermechanismen als co-constructie en transformatie van kennis. De ogenschijnlijke onverenigbaarheid van communicatie en structuur in een diagram kan mogelijk opgelost worden door communicatie en structuur als twee taken te scheiden, of door leerlingen te leren hoe ze kunnen redeneren via diagrammen.

Meer in het algemeen is er een probleem van transfer of vertaling tussen verschillende representaties of verschillende fasen in een taak. Veel paren leerlingen leken representaties als chat en diagram en fasen in een taak te zien als ongerelateerde activiteiten. Ze chatten bijvoorbeeld uitgebreid over het onderwerp, maar gebruikten niets van hun chat-discussie in hun diagram. Vanuit een onderwijs perspectief zou je daarom taken niet kunstmatig moeten scheiden. Vanuit een onderzoeksperspectief zou het echter wel interessant zijn om argumentatieve subtaken als samenvatten, tegenargumenten geven, en conclusies trekken te scheiden om zicht te krijgen op hoe leerlingen representaties gebruiken in deze subtaken. Conclusies van onderzoek naar deze kunstmatige scheidingen kan antwoord geven op de vraag waarom leerlingen representaties op een bepaalde manier gebruiken en kan ons helpen in het ontwerpen van tools.

Een sterk punt van het onderzoek in dit proefschrift is de holistische benadering waarmee de samenwerkingsprocessen werden geanalyseerd. De gebruikte analysemethodes analyseren het samenwerkingsproces in representaties en in fases als één geheel, waardoor we bijvoorbeeld inzicht kunnen krijgen in hoe de ene representatie wordt gebruikt als input voor de ander. Het quasi-experimenteel design kan problemen hebben veroorzaakt. De studies zijn allemaal uitgevoerd in scholen, waarbij condities gebruikt werden om variatie aan te brengen. Variatie tussen paren in een conditie was echter vaak groter dan variatie tussen condities. Dit kan te maken hebben met veel andere variabelen in een schoolsetting die ik niet heb meegenomen in het onderzoek, zoals schoolcijfers van de leerlingen en vriendschappen, maar ook met de mogelijkheid dat de verschillen tussen condities te klein waren om variatie te detecteren.

Toekomstig onderzoek zou zich moeten richten op de vraag waarom leerlingen zo verschillend werken aan een taak. Ik heb verschillende soorten diagram-gebruik gespecificeerd; diagrammen als medium voor discussie, als input voor verdere discussie, om informatie te kopiëren, om nieuwe informatie te ontwikkelen, om kennis te transformeren, om informatie te structureren, enzovoort. Het zou nuttig zijn om te onderzoeken waarom leerlingen bepaalde activiteiten kiezen, afhankelijk van hun samenwerking en de taak die zij moeten uitvoeren. Hoe stemmen leerlingen hun activiteiten af wanneer zij samen een diagram construeren? Andere waardevolle richtingen voor vervolgonderzoek zijn onderzoek naar transfer problemen en nader onderzoek naar secundaire notatie, om leerlingen te helpen diagrammen zo optimaal mogelijk te maken en gebruiken. Ik wil hiermee niet zeggen dat er maar één goede manier is om een diagram te maken die wij aan leerlingen moeten leren, maar leerlingen zouden wel kunnen leren hoe te redeneren via diagrammen om een goede debatruimte te creëren.

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Having two parents working in education kind of made it inevitable that I would follow in their footsteps. Of course I needed to be headstrong and became an educational psychologist instead of a school teacher. Mama, thanks for always being supportive and interested in my work, and for your patience when I was busy again. Papa, this dissertation is for you. I will never forget your enthusiasm for your school children. I hope you would have been proud of me.

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Marije

Curriculum Vitae

Marije van Amelsvoort was born on May 27th 1973 in Eindhoven, the Netherlands. She completed her secondary schooling in 1991 at the Augustinianum in Eindhoven. She studied Psychology at Tilburg University and graduated in 1998, specialising in Educational Psychology. Her master's thesis, a collaborative learning activity with a fellow student, dealt with secondary school students' subjective learning theories on the topic of Biology. From 1998 to 2000 she worked at FSR Opleidingsgroep, where she developed online courses for libraries and police forces.

In 2000 Marije started working at the Department of Educational Sciences at Utrecht University as a junior researcher in the European SCALE project. The project aimed at developing internet-based tools to support argumentation-based learning for secondary school students. After this project was finished in 2004, she was asked to write her thesis at the department, partly based on her work in the SCALE project. In 2005, Marije was granted a Marie Curie fellowship to work at Nottingham University in the United Kingdom for three months, where she carried out the fourth study of her dissertation.

Marije currently works at the Communication and Cognition Group at Tilburg University as Assistant Professor, where she combines research and teaching. She is also involved in the European LEAD project, in which research from the SCALE project and this dissertation is continued.

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