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

Marije van Amelsvoort [a,*], Jerry Andriessen [b,1], Gellof Kanselaar [b,1]

[a] *Communication and Cognition Group, Tilburg University, Warandelaan 2, P.O. Box 90153, 5000 LE Tilburg, The Netherlands*

[b] *Research Center Learning and Instruction, Utrecht University, Heidelberglaan 1, 3584 CS Utrecht, The Netherlands*

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Abstract

When students learn together by discussing a topic, they sometimes are asked to construct an argumentative diagram. An argumentative diagram consists of boxes with arguments and arrows that relate these boxes. Constructing argumentative diagrams can be especially useful for structuring and relating argumentative knowledge. However, students do not always seem to use a diagram's structure and relations to their benefit. To focus on structure and relations, 46 secondary school students were asked to either label the boxes in a diagram with argumentative labels such as 'argument in favor' and 'rebuttal', or to label the arrows with more causal labels such as 'but', and 'because'. The students discussed two topics in dyads using a computer environment with chat and diagram. Then a post-test was given to assess their opinion and arguments. We found no difference between conditions in the extent to which students broadened and deepened their discussion. However, students who labeled the arrows contrasted subtopics more. The students who contrasted subtopics more showed better results on the post-test. Instruction and diagram design can thus influence students' discussion, although the general results also show us that students need more instruction and reflection to optimally benefit from argumentative diagrams.

* Corresponding author. Tel.: +31 13 4663579.
E-mail addresses: m.a.a.vanamelsvoort@uvt.nl (M. van Amelsvoort), j.e.b.Andriessen@uu.nl (J. Andriessen), g.kanselaar@uu.nl (G. Kanselaar).
[1] Tel.: +31 30 2534940; fax: +31 30 2532352.

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1. Introduction

The goal of our research is to investigate how students structure and relate argumentative knowledge in a computer-based environment. There are different ways to represent and support argumentation with computers. Van Bruggen and Kirschner (2003) distinguish discussion-based tools and knowledge representation tools. In discussion-based tools the environment offers students the opportunity to exchange arguments, but the structure of argumentation is not explicitly represented. Knowledge representation tools, on the other hand, also offer an overview of the structure of argumentation.

Argumentation-based learning, described as an activity in which two or more people construct knowledge by discussing a topic together, could benefit from both. Chat-based discussion can be complemented with argumentative diagrams for example. 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 organizing diagrams.

In this article, we highlight the structural and relational benefits of argumentative diagrams. We investigate whether labeling 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.

2. 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). Advantages of dialogic argumentation using chat over face-to-face argumentation are that social factors such as status are less evident (Tan, Wei, Watson, & Walczuch, 1998), and that the communication is slow, allowing learners to re-read and reflect on information (Veerman, 2000).

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 realize 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 and it is very hard to get a good grip on the space of debate through temporal linear discussion. Learners may need instruction or tools to match linear interaction with non-linear argumentation. In the next section, we will therefore elaborate on the structure of argument.

2.1. 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) 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 analyzed 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

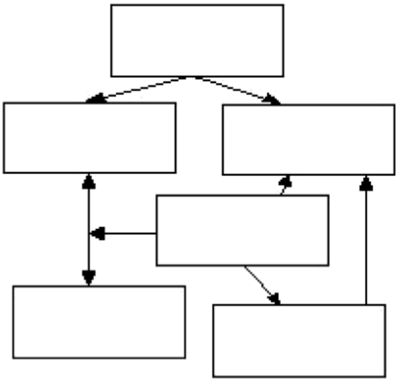

Fig. 1. Argumentative diagram can show non-linearity and multiple relations.

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.

2.2. *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 Fig. 1). 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.[2] We may infer that the structure is constructed in concepts and relations by means of argument, and that knowledge is thereby constructed.

3. 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 molding ideas from both learners.

[2] We do not want to imply that the external structure of the diagram resembles a structure in someone's head. First, we do not 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.

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 use chat and diagram for different activities (e.g., Munneke et al., 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 a 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 the between-structure that diagrams are able to show that is what 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 favor 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 to discover the complexity and inferences of the issue, and come to a well-supported view.

3.1. Labeling 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 e.g., Munneke et al., 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 labeling 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 favor, 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 reorganize 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, because the labels (viewpoint, argument in favor, argument against, support, rebuttal, example) are focused on lines of argument. Labeling 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, because the labels such as 'but' and 'and' can be used to relate different lines of arguments. Labeling 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?

4. Method

4.1. Participants

Participants were 46 students (13 boys and 33 girls in 23 pairs) aged 15–17 from two upper secondary schools in the Netherlands. The teachers of the two participating classes agreed to participate after receiving a letter and phone call explaining the general aim of our research into computer-supported collaborative argumentation-based learning. Since the innovation

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 via a computer environment, using chat and collaboratively constructing a diagram to reflect the integration of their arguments. Then they debated about two cases, one at a time, and put their ideas in a diagram. Dyads either labeled 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 8–10 students (not further discussed in this article)	60

Note. Time is given in minutes.

Dutch secondary education went through since 1999, actively acquiring and collaboratively constructing knowledge in project-based settings is very important (Stuurgroep Profiel Tweede Fase Voortgezet Onderwijs, 1994). Moreover, ICT is an essential part of this innovation. Students learn how to work with computers, and computers are also used as a means to reach educational goals. Students use computers and chat regularly, have classes on argumentation, but are not used to constructing argumentative diagrams on a computer.

Pairs of students were randomly formed within classes. Students within a pair each worked at their own computer, either as far apart in one room as possible, or in two different rooms. Pairs were randomly divided into two conditions (diagram with labeling boxes; diagram with labeling arrows). Three pairs were taken out of the analyses because of absenteeism, leaving data of 20 pairs for further investigation.

4.2. 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 favor*, *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*, and *such as*.

4.3. Materials

4.3.1. Tool

The computer environment we used in this study is called DREW (Corbel et al., 2002), developed within the European SCALE project[3] (see Fig. 2). The screen is divided in a

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

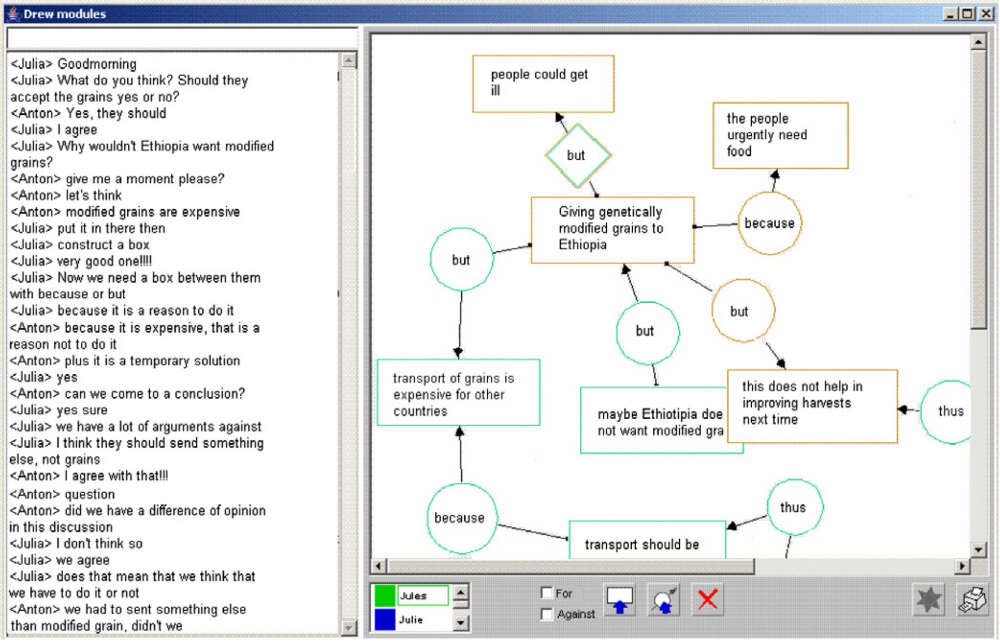

Fig. 2. Screen dump of DREW with diagram window, translated from Dutch into English (labeling arrow-condition).

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. The tool was the same for the two conditions, i.e., every student could label both boxes and arrows. Not the tool, but the instruction divided the conditions; students were asked either to label boxes or arrows.

4.3.2. Information sources

Students received 10 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 organization (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).

4.3.3. Assignments

Students worked together on two fictitious cases about GMOs, instead of discussing the pros and cons of GMOs in general. This was done to give them more grips 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 second case was about whether or not to genetically modify chickens in order to have more chickens in a small place, and to have chickens that have more meat and lay more eggs. Students were specifically asked to consider these cases from different perspectives. Cases were not crossed because of the relatively small number of students.

4.3.4. 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 last question was aimed at identifying whether students had changed their opinion based on the discussion with their partner.

4.4. Methods of analysis

To answer the first research question about differences between an argumentative and a causal diagram on how students explore the space of debate, we used four kinds of analyses: Rainbow for general activities students perform, broadening and deepening for the extent to which students explore the space of debate, using argumentation, and structure and relations to see how students transform knowledge together in the argumentative diagram.

4.4.1. Rainbow

The Rainbow framework (Baker, Andriessen, Lund, Van Amelsvoort, & Quignard, in press) defines students' general collaborative activities in seven categories (see Table 2). It provides information on frequencies of activities, for example, how many of students'

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

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 analyzed both in chat and in the collaborative diagram. Interrater agreement on ten protocols was .82 (Cohen's Kappa).

4.4.2. 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 (Van Amelsvoort, Andriessen & Kanselaar, 2007). We counted the number of subtopics students mentioned during their collaboration. If a topic was addressed multiple times, it was counted once.

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: claim, supportive, alternative, counter, rebuttal and evidence. We do not only count frequencies of these argumentative moves, but also sequences (see Fig. 3).

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.

We distinguish different sequences in a discussion by scoring all sequences that occur and the length of the sequence. Moreover, we distinguish whether students perform a deepening activity themselves (give), or asked their partner to do that (ask). It is not important how much each person contributes, because one remark of a student can be more important than 10 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.

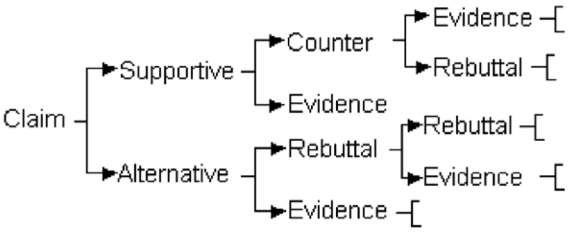

Fig. 3. Sequence of argumentative moves.

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. We distinguish between three kinds of argumentative sequences (see Andriessen, Erkens, Peters, Van de Laak, & 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.

Note that broadening and deepening the space of debate is scored over the combination of chat and diagram, following the flow of discussion. Students can use chat and diagram at the same time. A sequence can thus start in diagram and go on in chat for example. In Table 3, we see an example of an argumentative sequence of support–counter–rebuttal in which two students interact in both chat and diagram (moderate argumentation).

Interrater reliability between two judges on 10% of the data reached .75 for breadth and .77 for depth (Cohen's Kappa).

4.4.3. 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 analyzed 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. Fig. 4 is an abstraction of a 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 analyzed 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*.

Table 3
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 do not need employees if there is no harvest, so no harvesting, so the employment returns	Give rebuttal
Maria	Chat	That is true	Agreement

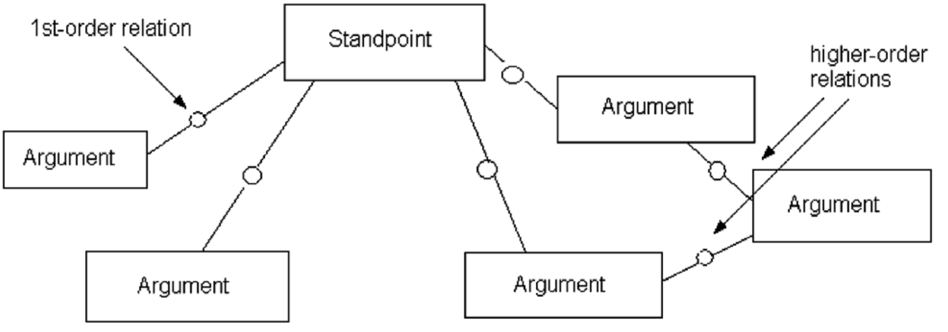

Fig. 4. Diagram with first and higher-order relations.

All first-order relations were categorized 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 people didn't do that in the past either". A relation of ownership justifies a claim with an argument of ownership, for example: "Peter is stubborn, because he is a real Dutchman" – implicitly arguing that all Dutch people are stubborn.

5. Results

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

5.1. Rainbow

We first performed a Rainbow analysis to see what activities dyads carried out during their collaboration in chat and diagram. Fig. 5 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 (seven 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.

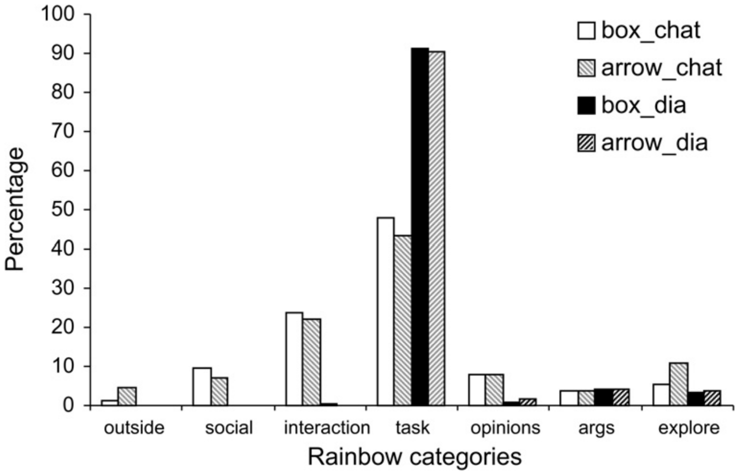

Fig. 5. Rainbow percentages for the two conditions label-box and label-arrow, divided into activities done in chat and in diagram.

5.2. 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 $t_{chat}(18) = 1.21$, $p = .24$, and $t_{dia}(18) = .33$, $p = .75$. 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 randomized, 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 = 2.2), and five topics in the diagram (SD = 1.5). The numbers of argumentative moves can be found in Table 4. 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).

5.3. Sequences

Broadening and deepening the space of debate was analyzed 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.

Table 4
Means and standard deviations for deepening the space of debate

Give/ask	Argumentative move	Chat		Diagram	
		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

Table 5
Argumentation in sequences

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

When taking all sequences of all pairs in two cases together, a total of 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 one move). A repeated-measures design on number of 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, $F(1,17) = .10$, $p = .75$. Again, results on the second case are better than on the first case, but there was no difference between the label-box and the label-arrow condition.

Table 5 shows the occurrences of minimal, moderate, and elaborate argumentation. We distinguished the sequences of argumentative moves that were made only in chat, only in the diagram, and the sequences that move from chat to diagram and/or back. This way we can see whether argumentative sequences occur mostly in either chat or in diagram, or whether students relate the two tools in their discussion. 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.

5.4. Labeling 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 favor, 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 nine with eight arrows connecting them, in the label-arrow condition 10 with nine 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 ($M = 11.55$, $SD = 6.12$) than the label-box condition ($M = 7.83$, $SD = 4.37$). In the label-box condition, 71% of all labels were used correctly, that is, a box that was labeled '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 sometimes also spontaneously labeled the arrows (e.g., they labeled the arrow leading to their conclusion with 'thus'), 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 ($M_{box} = 1.00$, $SD_{box} = 2.40$; $M_{arrow} = .59$, $SD_{box} = 1.53$), 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 favor' (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 labeled at all; 16% of boxes in the label-box condition were not labeled, while only 1% of the arrows in the label-arrow condition were not labeled.

5.5. Structure and relations

The diagram in both conditions is meant to structure the argument, showing how arguments are related. We therefore analyzed all relations (i.e., the arrows between boxes) that students created 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. Only 23% was third-order or higher. This means the diagram has a shallow appearance (see Fig. 6).

5.5.1. First-order relations

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

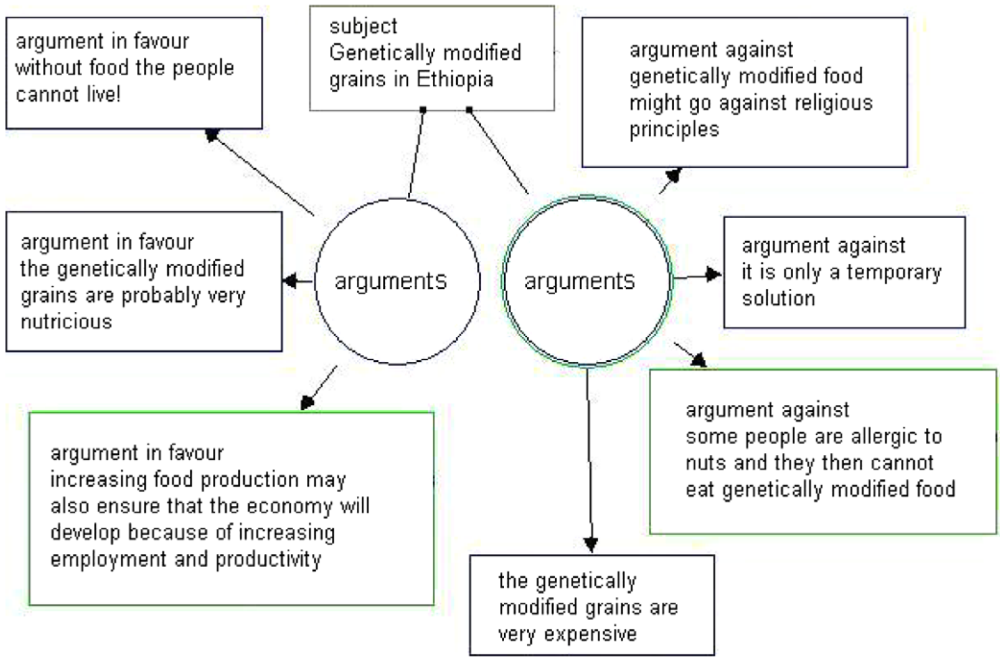

Fig. 6. Example of a diagram in label-box condition with only first-order relations (translated from Dutch into English).

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.

5.5.2. Higher-order relations

Fifty-three percent of all relations (186) in the diagram were second-order or higher (47% was first 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 ($f_{\text{box}} = 21; f_{\text{arrow}} = 28$) but students in the label-arrow condition contrasted topics more than twice as much ($f = 20$) as students in the label-box condition ($f = 7$).

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").

5.6. Test

The test 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 analyzed 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 ($r_{\text{topics}} = .50$; $r_{\text{arguments}} = .56$, $p < .05$ on the first case; and $r_{\text{topics}} = .44$, $p < .05$, $r_{\text{arguments}} = .26$, $p = .24$ 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 labeled arrows, not for the ones who labeled boxes.

6. 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 labeling diagrams seems to be beneficial for the learning process. 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 15–17 (Golder & Coirier, 1994), our subjects' age. Thus, the use of counterarguments is probably fairly new to them. Labeling 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. However, we think it is more important to investigate the effects of varying conditions of learning with diagrams rather than testing learning with diagrams against learning without diagrams (see also Dillenbourg, Baker, Blaye, & O'Malley, 1996).

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 do 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 et al., 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 et al. (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. Labeling in our study may not have been 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. Another option is to provide a script (Weinberger, Ertl, Fischer, & Mandl, 2005) to label boxes or arrows.

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 (although we cannot be certain, because the order of the cases was not controlled for). 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 did not find immediate effects of labeling the diagrams on broadening and deepening the space of debate, labeling 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 labeled *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.

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