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Perspective taking and synchronous argumentation for learning the day/night cycle

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Abstract Changing practices in schools is a very complex endeavor. This paper is about new practices we prompted to foster collaboration and critical reasoning in science classrooms: the presentation of pictures representing different perspectives, small group synchronous argumentation, and moderation of synchronous argumentation. A CSCL tool helped in supporting synchronous argumentation through graphical representations of argumentative moves. We checked the viability of these practices in science classrooms. To do so, we investigated whether these practices led to conceptual learning, and undertook interactional analyses to study the behaviors of students and teachers. Thirty-two Grade 8 students participated in a series of activities on the day/night cycle. Learning was measured by the *correctness* of knowledge, the extent to which it was *elaborated*, the *mental models* that emerged from the explanations, the *knowledge integration* in explanations, and their *simplicity*. We showed that participants could learn the day/night cycle concept, as all measures of learning improved. For some students, it even led to *conceptual change*. However, the specific help provided by teachers *during* collective argumentation did not yield additional learning. The analysis of protocols of teacher-led collective argumentation indicated that although the teachers' help was needed, some teachers had difficulties monitoring these synchronous discussions. We conclude that the next step of the design-research cycle should be devoted to (a) the development of new tools directed at helping teachers facilitate synchronous collective argumentation, and to (b) activities including teachers, designers, and researchers for elaborating new strategies to use these tools to improve the already positive learning outcomes from synchronous argumentation.

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The educational field has always been the hallmark of stability in society. To a large extent, it preserves today this feature of carrier of tradition. However, many innovators follow Dewey to consider the educational field as an arena for foreseeing societal changes and for preparing children for these changes. Thus, schools are nowadays the stage for both traditional and progressive approaches, and they are often the stage for struggles between them. In this situation, innovators have mixed feelings that range from excitement to puzzlement. Excitement comes from the innovations at sight and from the readiness of many to try out new ideas instead of just preserving perennial values, to envisage new tools, new practices and roles to fit noble ideals towards the construction of a better society. And indeed at least three powerful ideas have spread over the educational community during the last two decades. The first one concerns the fact that learners should be agents in constructing their knowledge. The second idea is that learners should collaborate with others in a productive way. The third idea is that learners should act according to norms of critical reasoning. Since many of the innovators adopt a cultural-historical approach in the way they see change, technological tools have been developed to support the realization of these ideas: for example, Knowledge Forum, Co-Lab, the Web-Based Inquiry Environment (WISE), and the Thinking Together Web resources. To a large extent, most of the tools developed were designed to foster all of the three ideas. These tools are impressive and in light of the ideals they convey, innovators can rightly be excited.

Besides the justified excitement that the implementation of each of the aforementioned ideas entails, the envisioned change raises serious concerns. First of all, by definition, each of these ideas defies old practices and structures. The challenge to the old is of course primarily ideological but if they want to be convincing, its proponents must show improvement. Two lines of argument have been adopted to show improvement. Some measured the impact of programs dedicated to the above ideas by comparing performances according to old criteria and evaluation tools. Such an approach is problematic since it favors programs designed to fit these criteria. Thus, unsurprisingly, this approach often leads to negative or mixed results (e.g., Arnseth and Säljö 2007; Linn et al. 2004). Q1

Other proponents decided that the separation from the old values should be total, and adopted ways to describe new practices which are incommensurable with the old ones. Divorce, rather than comparison and impact, is more fashionable nowadays at the time of such powerful ideas, when technology is harnessed to facilitate their implementation and when excitement reaches its apogee. The descriptions proposed to give good reason for the new practices are generally complex and difficult to follow though, and one can often ask to what extent the synergy between tools and human action enables agency or hides its absence.

This concern has been bluntly expressed by Rasmussen and Ludvigsen (2009), 2010) Q2 in arguing that some of the tools simply do not do the job, and that fine-grained interactive analyses are needed to evaluate whether tools or environments actually boost the ideas they have been designed to boost. But as just said, (interactive) analyses are often difficult to follow and cannot be used easily to show why new practices are preferable to old ones.

Even if there are already several islands of success in which some of the above ideals and tools have been implemented—advances that anticipate exciting times—these early birds of deep change in educational practices and values hide very difficult times to come.

First of all, projects carried out in the school context according to the above progressive approaches frequently fail to improve the student's conceptual understanding or higher level skills (Haakarainen et al. 2004). Also, the role of the teacher is either ignored, or acknowledged in general terms as being central (Hakkarainen 2010). The teachers with whom successes are reported are exceptional and convinced from the beginning of the desirability of the novel practices (Hakkarainen 2010). However, new practices do not emerge ex nihilo but from existing structures, from ways to interact, to teach, to evaluate or to praise as stressed by Engeström with his model of "expansive learning" (Engeström 1987). Yet, most of the studies that report on new practices do not trace how those practices emerged from old ones. The way practices take hold in schools is often described as the constitution of a learning community in the classroom that is presented as a kind of *tabula rasa* in terms of social norms, practices and knowledge, and gradually becomes acculturated to desirable norms, practices and knowledge. It has not yet provided a sufficient body of research (see Schwarz and de Groot 2010, though), although it appears to have a great deal of promise for investigating the change of educational practices.

Our goal in this paper is to instigate new practices and to study the transition from old to new practices: we check whether instigating the implementation of practices of critical and dialogic thinking with CSCL tools in science classrooms can lead to conceptual change, a learning outcome which is recognized as highly valuable according to both "old" and new values. We first explain that two practices that are very often enacted to foster critical and dialogic thinking—small group e-argumentation, and perspective taking with pictures—have the potential to lead to conceptual change in scientific topics, but that the potential is not easily capitalized on without additional facilitation. We then describe a graphical CSCL tool, the Digalo software that was designed especially to foster critical and dialogic thinking. In this environment in which the two above practices are elicited, we check whether Grade 8 students can learn the concept of the Day/Night cycle—whether conceptual change occurs. We adopt two kinds of methodologies for this purpose. First, we measure effects that reflect the old educational goals, practices and values, by observing conceptual change in a pre-test post-test setting. Secondly, we carry out an interactional analysis in two case studies to understand how the conceptual change was fostered or inhibited. This multiple methodology approach is not only a way to provide depth to conclusions drawn from inferential statistics, but also to enable a transition from old practices to new ones in institutions that are dedicated to innovation but which need to justify the implementation of the innovative practices against different stakeholders.

This methodological approach enables us to investigate whether teachers are efficient in facilitating the two aforementioned practices. We show that, although conceptual learning of the day/night cycle occurred in students, teachers have difficulties in facilitating small group e-moderation. We conclude that the combination of synchronous e-argumentation with inquiry-based activities supported by CSCL tools has an immense potential for learning scientific concepts, but that exploiting this potential is mainly an issue of constituting a learning community in which the role of the teacher should be meticulously rethought.

We will now show why instigating collective argumentation can foster collaboration and critical reasoning. We then explain that this activity is very difficult to sustain and that CSCL tools have been elaborated to support this aim. We explain then that this practice should be integrated with practices that handle the consideration of evidence to enable conceptual learning in science classrooms.

Argumentation for fostering critical reasoning and collaboration in science classrooms

Argumentation has been quite recently recognized as central in science classrooms for diverse reasons. First, direct observations of scientists in action (e.g., in their laboratories) showed that the discourse of science in-the-making involves a great deal of dialectical argumentation strategies (Dunbar 1995; Latour and Woolgar 1979; Longino 1994). Also, the diffusion of ideas among the scientific community was observed (Collins and Pinch 1994), and demonstrated the importance of rhetorical devices in arguing for or against the public acceptance of scientific discoveries. These observations led educators to infer that as argumentation in its different forms is the language of science for professional scientists, thus it should be the language of learners in science (Driver et al. 2000). The term 'argumentation' serves multiple functions, though. First it involves reasoning, when reasoning is used in argumentation to increase or decrease the acceptability of a certain standpoint or solution (van Eemeren et al. 1996). It is also a social activity that presupposes the presence of an audience (Walton 2006) with which one enters into dialogue. Researchers in science education have fostered argumentation for either function. For example, Osborne et al. (2004) have initiated teachers' programs to foster argumentation as a dialectical activity for the development of critical reasoning and argument skills. Scott, Mortimer and colleagues (Mortimer and Scott 2003; Scott et al. 2010) have adopted a dialogical stance and work with teachers who develop with their students dialogic spaces to give answers to questions that did not exist before classroom talk. Argumentation here involves collaboration, even in cases of disagreement.

But argumentative talk, either dialectical or dialogical cannot be easily sustained in science. In a series of experiments, Asterhan and Schwarz (2007, 2009) checked whether dyads of students could learn the concept of evolution after being invited to discuss the solution of a problem on the issue. Asterhan and Schwarz showed that asking students to comply with norms of critical reasoning in their argumentation was not enough to yield dialectical talk, but that showing evidence before discussion and prompting to argumentative talk during discussion led to dialectical talk and to conceptual change after interaction. Howe, Tolmie and colleagues (Howe et al. 2000) showed that discussions were productive only when they were asked to reach consensus during their discussions after they undertook some experimentation and raised hypotheses. These controlled studies indicate that scripting argumentative talk does not lead to productive argumentative talk and subsequently to conceptual change unless it is combined with inquiry procedures. On the other hand, Sandoval (2003) claimed that students may participate in many inquiry-based activities for years without understanding the nature of science. However, Sandoval showed that when students are explicitly supported in reflecting on the kind of product their inquiry has/should have produced, understanding is often attained. Sandoval concluded that epistemic guidance for inquiry must be integrated with conceptual guidance, since students' ideas about the nature of science influence their efforts to conduct science activities (Sandoval 2003). He then recommended combining inquiry-based activities with argumentative activities, since argumentative activities (and not inquiry-based activities) may bring to the fore students' epistemological beliefs, thus integrating them with what they experienced in their inquiry. We express this claim the other way around—to be productive, argumentation in science should be combined with inquiry-based activities, since our purpose is to foster critical reasoning and collaboration through argumentation. The question is how these very different activities can be combined. This is a design issue.

The design of environments for combining inquiry-based and argumentative activities in science classrooms

Although the idea of implementing genuine scientific activities combining inquiry-based and argumentative activities is seductive, it is not easy to implement. Sandoval and Reiser (2004) claimed that inquiry-based learning should be put in a wide context of the questions the inquiry should answer and the meaning of the products the inquiry produces. But the most important recommendation for combining argumentation and inquiry-based activities consists of developing habits of mind for scientific argumentation and epistemic guidance for inquiry. This led to the elaboration of learning environments such as BGuILE (Reiser et al. 2001). BGuILE is certainly an impressive environment. However, the components that invite "argumentation" are meant to lead to the production of arguments in the same vein as the approach adopted by Erduran et al. (2004).

CSCL scientists have developed various computerized tools that bring general habits of mind in argumentation specifically for tasks in domains such as science as separate components. The CSCL scientists claimed that to push argumentative discussions to be more productive in specific domains, students should first be familiarized with argumentative practices. These tools include tools (1) using structure for the argumentation based on effective interactions, like Academic Talk (McAlister et al. 2004); (2) using technology for detailed scripting (Weinberger et al. 2005); and (3) using representations to constrain argumentative interactions, like Belvedere (Suthers 2003) (see Andriessen and Schwarz 2009 for a comprehensive review). We opted for the third possibility since the constraint—the provision of graphical representations of argumentative moves—does not impair the flow of the discussion. We developed the Digalo tool (http://www.argunaut.org) which mediates argumentative discussions by enabling the co-creation of maps built of written notes inside different shapes, where different arrows (supporting, opposing, and linking) represent different connections between the shapes, and in collective argumentation enabling reference to each other's ideas. Every map has an ontology that specifies and constrains the admissible labels for the shapes (such as "claim", "argument", "explanation", "evidence", "question"). Figure 1 shows a part of a Digalo map. The upper tool bar includes argumentative components: "claim", "argument", "explanation" and "question", and the arrows "support", "oppose" and "link". Figure 1 displays four discussants (with a distinctive identification badge) and one moderator (whose background is colored). As shown by Schwarz and Glassner (2007), the constraints provided by the tool afford productive reference to the other and more relevant claims and arguments.

The Kishurim program—a program dedicated to fostering dialogic and dialectic thinking in schools—capitalized on Digalo extensively (Schwarz and de Groot 2007). The domains in which it was used were civic education (through discussions about moral dilemmas within Digalo) and history. As for science classrooms, the complexity of the combination of argumentative activities with inquiry activities led us to instigate a European Community initiative, the ESCALATE project (www.escalate.org.il). Its activities involve collaborative exploration of concepts and ideas through experimentation, hypothesis formulation, testing, and building on intuitive knowledge though collective argumentation. The Digalo tool is designed to enable students to engage in collective argumentative. Students were also provided with tools for undertaking experiences and collecting data. For example, a microworld was used to model collisions between physical bodies of different weights in different conditions of friction. Other microworlds were used to collect data in astronomy, electricity, or biology. The environments created in five

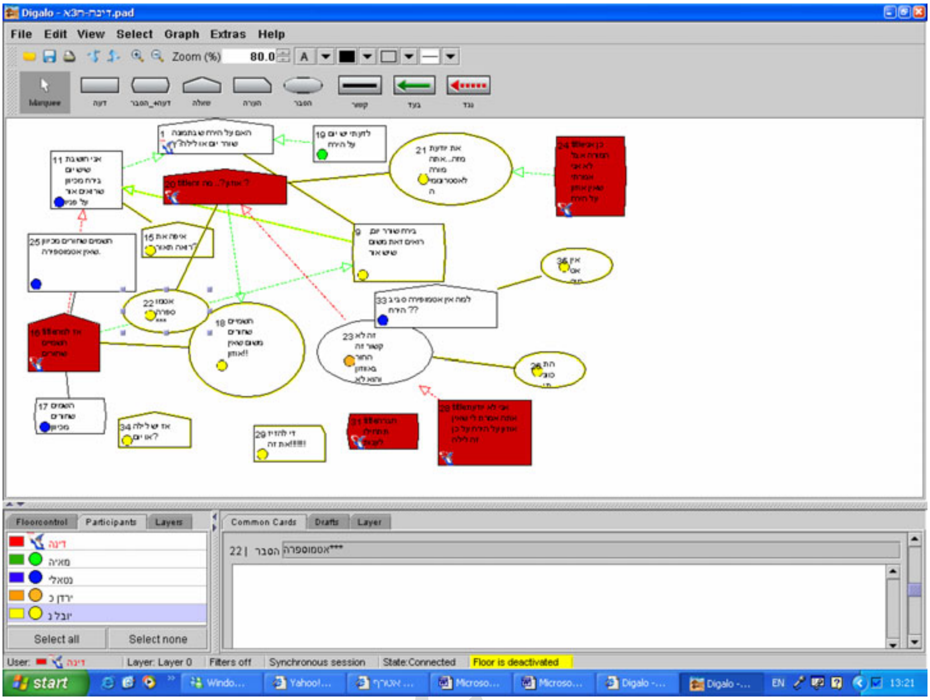

Fig. 1 An example of unfocused discussion with four discussants and one teacher

European countries and the pedagogical/organizational efforts invested to combine inquiry and argumentation strategies are described in the *White Book* (Schwarz 2008). In the present paper, we describe one of the experiments conducted within the ESCALATE project regarding the day/night cycle.

So far, we suggested using Digalo as a representative of computer-supported collaborative argumentation tools to familiarize students with norms of scientific argumentation and tools for undertaking experiments or collecting data. But the provision of tools, sophisticated as they may be, is not sufficient to boost collaborative reasoning in science. A necessary aspect of any program for boosting collaborative reasoning in science is to envisage the kinds of instruction students are given. Some researchers have investigated techniques such as scripting collaboration or argumentation (Rummel and Spada 2005; Rummel et al. 2009; Stegmann et al. 2007). However, members of the ESCALATE project have decided to investigate direct structuring of students' on-going talk by teachers. Such a practice has rarely been considered in collective e-argumentation. Since we are committed to socio-cultural principles, we envisaged human mediation as an "e-moderation" to express the fact that guidance is non-intrusive while caring (Asterhan and Schwarz 2010). Several pilot studies suggest that e-moderation of synchronous collective argumentation may be feasible with Digalo. The ESCALATE project, which was initiated for fostering the learning of science through inquiry and argumentation, gave us the opportunity to investigate the viability of e-moderation practices in synchronous collective argumentation and its combination with a basic inquiry-based activity—perspective taking. It also enabled us to investigate how teachers function in this combination. Q4

Perspective taking as a basic inquiry strategy in science

Perspective taking—opening a new perspective concerning an issue at stake, is ubiquitous in reasoning. In science, perspective taking is essential in order to learn scientific phenomena. Children have views of scientific phenomena that are rooted in their direct observation of the world (e.g., Vosniadou and Brewer 1994). As children develop, they are confronted with different perspectives, and they integrate them with their intuitive preconceptions that are rooted in direct observations, to build conceptual learning (Vygotsky 1987). Their initial knowledge becomes *synthetic* as they integrate models, explanations, and symbols provided by more knowledgeable people who mediate this integration (Kikas 2004). For example, Schoultz et al. (2001) showed how the presence of Q5 a material globe could help grade 2 students in reasoning about the Earth in a way which was much more advanced than in structured interviews without any material device (like in Vosniadou and Brewer's study). They could capitalize on information from the globe through a dialectical process conducted by the interviewer. However, it is not clear whether the use of a globe by grade 2 students leads to integration of knowledge, even if explanations seem more elaborated in the presence of the globe. Continuous mediation is indispensable to sustain motivation, to point at differences and apparent contradictions between the perspectives, and to integrate them (Schur et al. 2002; Schur and Kozulin 2008). We borrowed activities designed from the *Thinking Journey,* an educational initiative focused on the resolution of contradictions between perspectives, and by such, at overcoming problems of egocentricity in science education: students are invited to take part in a mediated journey to faraway places where they have to orient themselves (Schur and Galili 2008). When teaching physics, the faraway environments that students visit often concern astronomy. Such journeys can be realized with the use of pedagogical tools such as computerized models (Yair et al. 2003) or pictures (Schur and Galili 2008). The overt stipulation of the place to be considered by the learners in each perspective enables them to realize that in order to understand a phenomenon they should use multiple representations (like pictures) completing each other. As mentioned above, the instigators of the *Thinking Journey* were aware that this integration demands the mediation of a tutor to sustain motivation and to point out differences and apparent contradictions between perspectives.

In the next subsection we show why the concept of day/night cycle seemed to us suitable for initiating a program for exploring new practices in the science classroom.

The concept of the day/night cycle

The day/night cycle is a phenomenon children experience every day. They have explanatory schemes they use to explain to themselves or to others events linked to the cycle of day and night. Early models of the day/night cycle and of celestial bodies and phenomena are influenced in general by egocentricity in the sense that their understanding is rooted solely in direct observation of the self (Piaget 1977; Barnett et al. 2005; Kikas 2004; Nussbaum 1985). Research on the development of the day/night cycle concept has shown that even at late stages of development, it is difficult to understand. For example, Trumper (2001) has found that one third of high school students had no satisfactory explanation for this cycle. Baxter (1989) undertook a developmental study with students whose age ranged from 9 to 16 (only 20 students participated though). Interviews with these students uncovered six explanatory frames: the sun goes behind a hill, clouds covers the sun, the moon covers the sun, the sun goes around the earth once a day, the earth goes around the sun once a day, and the scientific model where the earth spins on its axis once a day. These explanatory frames helped in tracing developmental processes. Baxter showed that even adolescents often had beliefs such as the fact that the sun revolves around the earth during the day and that the moon revolves around the earth only during the night. Vosniadou and Brewer (1994) also studied the day/night cycle concept to draw general lessons on conceptual development in general. They discerned three stages of conceptual development from naïve models, to synthetic models integrating naïve and scientific models, to scientific understanding. Vosniadou et al. (2004) showed that simply providing correct models to students may increase scientifically correct responses (as shown in Schoultz et al. (2001) study), but may at the same time decrease internal consistency and inhibit the generation of internal models. It is then important to engage students in scientific activity combining argumentation and inquiry by providing pictures or models. We expected students to have similar egocentric views, and that inviting students to observe natural phenomena from different perspectives would lead to productive argumentation.

In summary, we hypothesized that by presenting different perspectives (through pictures), then inviting students to engage in collective argumentation in synchronous discussions and to participate in subsequent teacher-led reflective activity, the students would integrate the perspectives, leading to the learning of the day/night cycle. We adopted a *design-research* approach (Collins et al. 2004): the environment was elaborated in several iterations of design, formative assessment in ecological settings and implementation of changes and improvements (see the *White Book* (Schwarz 2008) for description of the iterations). As a part of the design-research program, we explored the viability of another practice—whether moderating collective argumentation would yield additional conceptual gains.

Description of the research

Two research questions were investigated:

1) Does the combination of perspective taking (mediated by pictures presented to students) and synchronous argumentation promote conceptual learning of the day/night cycle?
2) Does the mediation of the instructor in synchronous discussions contribute to conceptual learning?

Method

Participants

Forty four grade eight students from three different classes in two integrative middle-schools in Jerusalem participated in the experiment. All students mastered basic computer tools (Office, internet). Four teachers and two research students/experimenters (third and fourth authors) participated in the experiment. The teachers were experienced and highly motivated. They had already participated in Thinking Journey training activities in the past. Three out of the four teachers had already taught the "Thinking Journey to the Moon" program (Schur 1998) in their classes.

Tools

A questionnaire was constructed. This questionnaire asked students to explain the day and night cycle. Some of the items were: “Is there day and night on Mars? Explain” and the multiple choice question “What do you think causes the day and night cycle?”: (A) The sun hides behind the mountains, (B) Clouds cover the sun, (C) The moon covers the sun, (D) The sun revolves around the earth once a day, (E) The earth revolves around the sun once a day and (F) The earth rotates around its axis once a day. Six of the eight items were open questions.

The second tool consists of the Day and Night case. This case is organized in six steps, including (1) an individual activity in which each individual is asked to represent day and night graphically and to raise questions on day and night, (2) a classroom teacher-led face-to-face discussion on the drawings and the questions raised, (3–5) three small-group Digalo discussions supplied with increasing evidence in the form of pictures, and finally (6) a teacher-led concluding discussion. The pictures displayed day and night on the Earth and the Moon taken from different perspectives. For example, Fig. 2a displays the picture provided to trigger a Digalo discussion (step 3) on whether there is day or night on the place in the Moon where the picture was taken. Figure 2b (without the shadow projected on the ground of the Moon) displays additional evidence that nurtured another Digalo discussion (step 4). Some of the small group discussions were mediated by teachers or experimenters (see the procedure section).

Procedure

The teachers had prior knowledge about mediating students’ construction of knowledge by using Thinking Journey materials, but did not have any experience in working with Digalo. The two experimenters (the third and fourth authors) were trained in advance to operate

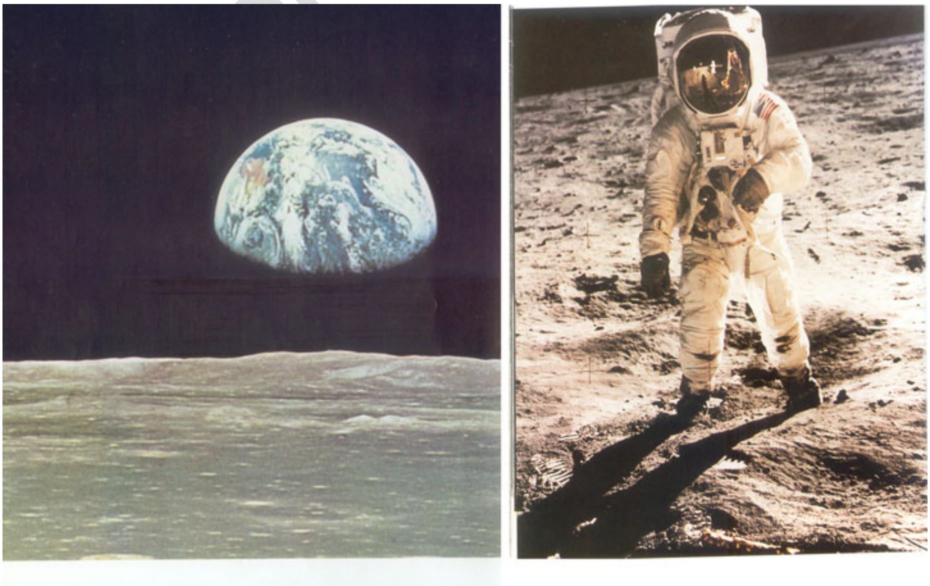

Fig. 2 Two pictures used to trigger Digalo discussions on the Day and Night cycle

Digalo and to conduct the Day and Night case. In order to prepare the teachers to participate in this study, an eight hour training seminar of two four-hour long meetings was organized. In these meetings, the first experimenter explained to the teachers that they should foster dialectical and dialogic argumentation in students. He articulated basic argumentative moves: claims, arguments, rebuttals, challenges, explanations, etc. Then, he presented Digalo to the teachers. The teachers experienced the tool by participating in a synchronous discussion on an educational issue (whether to use tools for e-discussions in school learning). Then, the second author distributed to each of the four teachers a booklet containing the pre-post test questionnaire and the Day and Night case. The teachers participated in the Day and Night case "as if they were students." Technical support was given by the research team. In the Digalo discussions, two groups of three participants were constituted. Each group included two teachers and one experimenter (the third and the fourth authors). A reflective discussion was held among teachers and the members of the research team after each part of the learning activity. The second meeting in the seminar was aimed at training the teachers how to mediate the activities constituting the Day and Night case, especially how to mediate Digalo synchronous discussions. In the Digalo discussions (again, two groups of three participants with two teachers and one experimenter), the teachers took turns, so that one of the teachers was defined as a 'student-discussant', while the other had to mediate the discussion.

In the reflective discussions that alternated with the running of the Day and Night case, the teachers complained at first that they had technical difficulties in using Digalo. This complaint gradually disappeared as they engaged more in e-discussions. The teachers believed that students would adapt faster to e-discussions. However, they suggested adding a preparatory activity to introduce students to argumentative norms, for example by choosing proper ontology for each of their interventions. They suggested discussing a social issue for such a preparatory activity. The teachers had concerns about managing the activity while sustaining sufficient motivation and discipline. They were assured that each class would receive both technical and pedagogical support, and there was a mutual agreement on the need to articulate desirable rules for discussions. A vivid debate focused on when and how to mediate e-discussions, and when to turn to face-to-face mediation. Different opinions were raised. Some claimed that the students would need more clues and information, while the others claimed that the debriefing should only be done at the end. From this discussion, it appeared that mediation strategies would depend on the teacher's pedagogical style and that no single mediation strategy would dominate e-discussions. However, the teachers and the experimenter agreed on rules which should be followed in discussions such as the obligation to provide reasons for claims or to try to challenge arguments when disagreeing arose. The teachers collaborated nicely although they were not always fully convinced of the necessity of synchronous tools for discussions.

The experiment began by organizing students in groups of three or four in the computer laboratory. Each student sat by a computer where a Digalo screen already appeared. Students were asked not to communicate orally. The students were briefly introduced to Digalo functioning, and participated in a preliminary task in the small groups formed in which they discussed a moral dilemma—the right to perform experiments on animals. Then, the students were asked to complete the questionnaire. At the next stage, the whole Day and Night case was implemented. It lasted three 90 minute long sessions. In each classroom, two groups were mediated by two teachers, one group by an experimenter, and two groups were not mediated. At the end of the case, each of the students was asked to complete the questionnaire again.

As mentioned above, we did not include any control group. The rationale for this decision was that we aimed to check whether the approach we adopted induced conceptual learning and even conceptual change—a radical change which was difficult to reach anyway. Our design research put the stress on a phenomenological rather than a comparative stance.

Collection and analysis of the data

Twelve of the 44 students did not complete the post-test. We then included 32 students in the analysis of the cognitive gains from the participation to the activity. All 64 questionnaires (32 for the pre-test and 32 for the post-test) were collected. Five aspects of the learning about the concept of the day/night cycle were measured by the questionnaire: 1) the *correctness* of answers; (2) the extent to which answers are *elaborated*; (3) their *simplicity*; (4) the *mental models* these answers express and (5) the extent to which the answers show *integration* of direct observations with other sources. Table 1 shows schematically how we operationalized these aspects. Concerning *correctness*, it could receive three marks, 0—incorrect answer, 1—partial correct answer, and 2—correct answer. For measuring *elaboration*, we formed a check list of ideas which must appear in each of the questions in order to receive a full answer. Each idea received one point. Each missing or incorrect phrase that was added received zero points. We summed the number of points and divided it by the number of the total phrases needed for a full answer+the incorrect phrases given by the student. *Simplicity* of the explanations expressed to what extent explanations for the day/night cycle became more similar when describing the day and night on earth, the moon, mars and other planets. We identified four levels of simplicity (see Table 1).

As for the identification of *mental models*, we analyzed all explanations provided by the students and analyzed their content in order to identify the mental models of the students. The previous frameworks proposed by Baxter (1989) and Vosniadou and Brewer (1994) fitted very young children with explanations such as "The sun hides behind a hill" which made it difficult to refer to the exact classification they proposed. We then decided to constitute a new classification. We identified six explanatory frames of the day/night and day cycle that convey six different mental models. We list here the explanatory frames and the inferred mental models in parentheses: (1) No explanatory frame (no mental model), like in the explanation "In daytime we are up and in the night we are sleeping"; (2) The sun revolves around the earth/planets (geocentric model) like in the explanation "The sun revolves around earth, lighting different parts each time"; (3) At day the earth revolves around the sun and at night around the moon (dual model) like in the explanation "In daytime the sun lights the earth and in the night the moon lights the earth"; (4) The earth revolves around the sun once a day (heliocentric model), like in the explanation "Day and night happens because the earth is revolving around the sun"; (5) The earth revolves around its axis, and the sun and moon are in two opposite sides of it (hybrid model) like in the explanation "Day and night happens because earth revolves around itself once a day, and each time half of it faces the sun and half faces the moon"; (6) The passage from day to night is caused by the fact that planets revolve around themselves (scientific model), like in the explanation "the earth revolves around itself once a day".

Finally, we analyzed all the explanations given by the students in their questionnaires in order to identify the way they integrated non-observable information in their explanations of the day/night cycle. We were interested in measuring the extent to which students freed t1.1 **Table 1** Operationalization of the five aspects of the learning of the day/night cycle

	Criteria	Range	Examples or clarifications
t1.2	Criteria	Range	Examples or clarifications
t1.3	Correctness of ideas	0 = Incorrect answer	Q: Is there day and night on the moon?
t1.4		1 = Partial correct answer	A: No, there is only night on the moon, because it's dark.
t1.5			Q: How would you explain to a friend the day and night phenomenon?
t1.6			A: The earth rotates around itself and around the sun. When the earth rotates, and a certain area is not lit, the sun begins to light it, since the earth also rotates around itself. (*The answer is only partly correct since it involves the fact that the earth revolves around the sun, which is not relevant for the day and night cycle*).
t1.7		2 = Correct answer	Q: Is there day and night on the sun?
t1.8			A: No, the sun is the source of "day", and there is no night there. It is always lit, so there is always "day" there, and no "day and night".
t1.9	Elaboration	Number of correct ideas divided by the total number of ideas given by the student. For each question, a checklist of ideas was prepared.	Checklist for: "Explain in your own words what day and night are":
t1.10			• The sun shines (on the earth)
t1.11			• Day and night exist in different areas of the same celestial body
t1.12			• Day = light
t1.13			• Night = darkness
t1.14			• The moving from day to night is created by the fact that celestial bodies rotate around themselves.
t1.15			Mistakes- any other idea, contradictory or irrelevant
t1.16	Simplicity	0: Different answers	A different explanation of the same phenomenon for different planets
t1.17		1: Non contradictory answers	An explanation for at least one planet and the rest is not contradictory (lack of knowledge, indecision).
t1.18		2: Partially identical	The same explanation for two of three planets (earth, moon, mars).
t1.19		3: Identical answers for all of the planets	The same explanation for all planets and a different explanation for the sun.
t1.20	Mental models	1: No explanatory frame	No mental model
t1.21		2: Geocentric model	The sun revolves around the earth/planets
t1.22		3: Dual model	At day the earth revolves around the sun and at night around the moon
t1.23		4: Heliocentric modell	The earth revolves around the sun once a day
t1.24		5: Hybrid model	The earth rotates around its axis, and the sun and moon are in two opposite sides of it
t1.25		6: Scientific mode	The passage from day to night is caused by the fact that planets rotate around themselves (scientific model).
t1.26	Level of knowledge integration	1: Egocentric:	Night and day are perceptions of the self. They don't happen to (parts of) the earth but to the self
t1.27		2: Geocentric:	The day and night cycle can happen only on earth

Table 1 (continued)

Criteria	Range	Examples or clarifications
	3: Nearly geocentric	The day and night cycle can happen on earth or in its near proximity
	4: Ubiquitous	The day and night cycle can happen on distant planets. Although this occurrence relates to 'receiving light', explanations remain fuzzy
	5:Phenomenological	The day and night cycle is recognized as a phenomenon which is ubiquitous, the explanation of this phenomenon being specific
	6: Universal	The day and night cycle is perceived as a universal law that governs a ubiquitous phenomenon occurring in the universe

themselves from explanations exclusively rooted in direct observation and integrated non-observable information. Six levels of explanations could be identified:

(1) *Egocentric*: Night and day are perceptions of the self. They don't happen to (parts of) the earth but to the self.
(2) *Geocentric*: The day and night cycle can happen only on earth.
(3) *Nearly geocentric*: The day and night cycle can happen on earth or in its near proximity.
(4) *Ubiquitous*: The day and night cycle can happen on distant planets. Although this occurrence relates to 'receiving light', explanations remain fuzzy.
(5) *Phenomenological*: The day and night cycle is recognized as a phenomenon which is ubiquitous, the explanation of this phenomenon being specific.
(6) *Universal*: The day and night cycle is perceived as a universal law that governs a ubiquitous phenomenon occurring in the universe.

Examples of answers to the questionnaire and their analyses are succinctly presented in Table 1. Two judges compared each of the explanations written; it was possible to maintain an agreement between the judges with Cohen kappa of 0.9. As it happens in literature on mental models and conceptual change, some variability could be perceived among the explanatory frames that the students used along the questions of the questionnaires. However, they appeared to be quite coherent. In cases of variability, the judges identified mental models according to the less sophisticated explanatory frame expressed in the questionnaire.

Analysis of the discussions

For answering the second research question, namely studying the role of the mediation of the instructor in knowledge construction through synchronous discussion, we developed tools for analyzing the discussions. We collected 12 discussion maps—eight maps of groups of four students, and four maps of groups of three students. These maps included the 44 students in the experiment, although only 32 of them completed the post-test. Overall, 180 mediation moves from teachers and experimenters were gathered and analyzed according to the following parameters: *Kind of mediator* (teacher or experimenter); *Stage in the discussion* (beginning, middle, or end); *Type of reference* (general—to all participants, or personal—to a specific participant); *Type of relatedness* (wide—relating to the wide topic of discussion, focused—relating to a specific point in the discussion); *Number of students to* *which the mediation move is directed*; *Type of mediation* (content oriented—relates to the topic of discussion, organizational—relates to aspects such as encouraging students to participate, and a correct implementation of the task). In addition to the mediating actions of the instructor, we also identified the *quality of students' reactions* in response to the instructor's moves (shallow—interventions that are irrelevant to the topic, deep—interventions that are relevant to the topic).

Students' responses were calculated by summing the number of direct reactions to each of the mediator moves. The other variables were evaluated by two judges using agreed upon rules (in the case of the mediation type—checking whether the mediation move deals with the topic of discussion or with maintaining the discussion). The overall inter-rater variability was high (Kappa=0.9). Figure 1 presented above displays an argumentative map with four discussants and one teacher. We can see examples of many types of interventions and responses to them. In the first turn, the question *is there day or night on the moon in the picture?* is wide and general and deals with the content. The students' replies are deep, since they directly relate to the question; Yuval, for example, says in turn 2 *there's day on the moon. You can see that because there is light*. Turn 5, the next step of the mediator *why is the sky black in the picture and refers to more than one student's' answer* is still general. Again it receives deep responses from the students, see for an example Natalie's answer in turn 6: *the sky is black because there is space surrounding it, but we see that the moon is lit, no matter what's around it*. The next mediation move, turn 9, is specifically related to Yuval's answer in turn 7, who says *the sky was black because there is no ozone layer*. The mediation move is focused on a specific word (Ozone) and it receives a shallower, and perhaps even a cynical response from the student (*you know what it is, you are an astronomy teacher* in turn 10). This is followed by another specific and focused mediation move (turn 13), and then an organizational mediation, when the mediator encourages the students to stay focused on the task of answering the main question (turn 18).

Results

In order to check the first research question, we ran a 2 (classes) x 2 (time—before, after) x 3 (mediator in synchronous discussions—none, teacher, experimenter) MANOVA test. Results showed a main effect for time on all dimensions of the first research question (Wilks' Lambda=0.49, F=4.54, p=0.005): for the *mental model* (F=7.64, p=0.01)—although 60% (19 out 32) did not hold the full scientific model after the activity, for *elaboration* (F=7.85, p<0.01), and for *simplicity* (F=4.64, p<.05). There was an increase in *integration* towards *universality of the day and night conception* following the activity (F=18.40, p<0.001)—students could see it as less related to the self, and more related to the earth, and as more general, principled, and ubiquitous. Surprisingly, this is precisely for *correctness* of answers than just a tendency towards improvement (F=3.61, p=0.068). A correlation between the type of mental model and the integration of sources of knowledge was also found (r=6.06, p<0.001(so that the more integrative the answer was, the more advanced was the mental model. No effect for class was found.

Concerning the second research question, no effect of mediation (by teacher or experimenter) was found. Moreover, the type of mediation was found to be in interaction for two of the dependent variables—*elaboration* (F=3.70, p=0.038) and *knowledge integration* (F=5.44, p=0.011) in a quite surprising manner: There was a greater improvement in those parameters when there was no mediation, or when the experimenter mediated, than when the teacher was the mediator.

As already mentioned, we also analyzed the mediation moves in the discussion according to the following parameters: Mediator, Mediation type (content oriented/organizational), Stage of the discussion (beginning/middle/end), Type of approach (general/personal), Type of relating in mediation (wide/specific), Directedness of the teacher, and Quality of interventions of students (deep/superficial). There was no effect of the stage in which mediation was provided on the quality and number of responses. The mediation moves that were content oriented received deeper responses ($F=22.24$, $p<0.001$; Beta=0.405, $p<0.001$) but were fewer ($F=29.66$, $p<0.001$; Beta=−0.263, $p<0.001$) compared to organizational mediation moves. The same was true for a personal approach in mediation, which received deeper responses ($F=22.24$, $p<0.001$; Beta=0.371, $p<0.001$) but were fewer ($F=22.24$, $p<0.001$; Beta=−0.495, $p<0.001$) compared to a collective approach. Finally, wider mediation moves received deeper (F=22.24, $p<0.001$; Beta=0.326, $p<0.001$) and more ($F=29.66$, $p<0.001$; Beta=−0.432, $p<0.001$) responses than a specific approach. The findings brought good news, the fact that combining argumentation with mediated perspective taking leads to conceptual learning of a scientific concept. We also found that human mediation in synchronous discussions had no effect on concept learning. Of course, this quite surprising finding did not mean that human mediation in the whole sequence of the Day and Night case did not help in conceptual learning: Steps 2 and 6 in the Day and Night case were teacher-led discussions for all students. Rather, the findings indicate that mediation *during* small group synchronous discussions (steps 3, 4 and 5) was not efficient. Still, such a finding demands clarification. The fact that conceptual learning was attained was quite surprising, too, and necessitates further explanation.

Analyzing discussions to better interpret the results

Among the diverse discussions we collected and analyzed, we decided to present two synchronous discussions moderated by a teacher to sharpen our understanding of the results obtained with inferential statistics—the overall conceptual learning of the students and the fact that moderation was ineffective. Figure 1 shows the map of the first discussion with four discussants, Yuval, Natalie, Maya and Yarden, and one teacher. Scrutiny over pre and post-tests of the discussants (not shown here) showed that the mental models of the participants that could be identified in the questionnaires after the interactions were not more developed than before the interactions (Yuval's level of integration increased, though). The map refers then to students who did not learn. We will see that the teacher failed to properly moderate a synchronous discussion. Of course, we don't argue that this failure necessarily caused the lack of learning but we consider it as a circumstance of the particular further lack of learning. The map is transcribed into a protocol in the following. The protocol includes the ontology used (question, explanation, etc.), the text (in italics), and finally the link created. The discussion begins with a clear question by the teacher that refers to the picture of the earth taken from the Moon:

1) Teacher, Question, *is there day or night on the Moon in the picture?*
2) Yuval, Explanation, *there's day on the Moon. You can see that because there is light* (support to 1)
3) Natalie, Opinion, *I think there is day on the Moon, because we can see light on its surface* (support to 1)
4) Yuval, Question, *where do you see the light?* (link to 3)
5) Teacher, Question, *why is the sky black?* (support to 2, opposition to 3)

6) Natalie, Argument, *the sky is black because there is space surrounding it, but we see that the Moon is lit, no matter what's around it* (link to 5)
7) Yuval, Explanation, *the sky is black because there's no ozone* (link to 5)
8) Maya, Opinion, *I think it is day on the Moon* (link to 1)

We see that in turns 2 and 3 Yuval and Natalie gave a correct answer based on the presence of light on the ground of the moon. Yuval's question to Natalie, *where do you see the light,* is petty since Natalie's answer in turn 3 is more or less a paraphrase of Yuval's answer in turn 2. This exchange looks like the beginning of a dispute. The teacher does not seem to be sensitive to this tension as he opts for challenging Natalie's answer by asking *why is the sky black?* This challenge is a good idea to initiate a dialectical process but is not well handled as it is displayed as a support to Yuval and an opposition to Natalie instead of being proposed as an opposition to both Yuval and Natalie. It thus exacerbates relations between Yuval and the other discussants. Natalie still tries to handle the teacher's challenge by declaring *the sky is black because there is space surrounding it, but we see that the moon is lit, no matter what's around it*. This contribution is an elegant way for Natalie to say that although she does not know why the sky is black, the fact that the surface of moon is lit suffices to infer that there is day on the moon. Interestingly in turn 7, Yuval answers the teacher's challenge to Natalie by directing it to Natalie, perhaps as a way to maintain his adversarial attitude towards her. He invokes the lack of ozone to justify the blackness of the sky. The fact that Maya answers to the main question at turn 8, without referring to what was written so far, suggests that she does not follow what happens between the teacher and the other discussants but deliberates with herself about the issue.

We will see that the teacher is not receptive to Maya's self-deliberation and that he directs his attention to Yuval's contribution in turn 7 to initiate a kind of dispute:

9) Teacher, Question, *Ozone? What's that?* (support to 7)
10) Yuval, Explanation, *you know what it is, you are an astronomy teacher* (link to 9)
11) Yuval, Explanation, *atmosphere* (link to 7, 9)
12) Yarden, Explanation, *the hole in the ozone has nothing to do with light on the moon* (opposition to 9)
13) Mediator Argument, *but I am the teacher, and I didn't say there is no ozone on the moon* (support to 10)
14) Natalie, Opinion, *the sky is dark since there's no atmosphere* (link to 5)
15) Yuval, Explanation, *I meant atmosphere* (link to 13)
16) Mediator, Opinion, *I don't know, you told me there's no ozone on the moon, so it is night* (support to 15)
17) Yuval, Comment, *Stop moving it!*

As we see, the teacher ignores Maya's opinion to react to the issue of ozone raised by Yuval in turn 7 through an aggressive *what's that?* in turn 9. From that point onward, the discussion loses its focus on the day and night cycle. It is nor dialectical neither dialogical but rather looks like a dispute: Yuval reacts boldly (*you know what it is, you are an astronomy teacher* in turn 10). In turn 11, Yuval corrects his irrelevant reference to ozone to claim that he meant that [the sky is black because there is no] *atmosphere.* In turn 12, Yarden rightly reacts to the teacher's aggressive remark in turn 9 by writing that the issue of ozone is irrelevant to the issue at stake. But the teacher, who probably reacts in parallel to Yarden, insists on focusing on ozone, seemingly because Yuval's intervention in Turn 10 was itself aggressive—expressed as an *ad hominem* argument. His reaction to Yuval (*but I am the teacher, and I didn't say there is no ozone on the moon*), positions him as a discussant with a special status for whom saying or not saying something (here that there is no ozone on the moon) should change the course of the discussion. But in turn 14, Natalie is not receptive to this authoritative intervention, and answers to the question that the teacher asked in turn 5 *the sky is dark since there's no atmosphere.* The teacher's authoritative intervention does not affect Yuval either as he insists again that he meant atmosphere instead of ozone. The teacher's reaction to Yuval in turn 16 shows that he totally lost control on the development of ideas as he declares *I don't know, you told me there's no ozone on the moon, so it's night.* The teacher even seems as if he lost the thread of his own thought—capitalizing on the fact that the sky is dark to challenge that there is light on the moon. This loss of focus turns flagrant at the end of the discussion:

18) Teacher, Argument*, Come on guys, start responding seriously to the main question*
19) Natalie, Question, *why isn't there atmosphere around the moon?* (link to 15)
20) Yuval, Question, *so, is there night or day?* (link to 18)
21) Yuval, Explanation, *there's no atmosphere on the moon because only certain planets have atmosphere* (link to 19)

We suggest that when the teacher asks the discussants *come on guys, start responding seriously to the main question*, this is a way to hide his disarray. Natalie does not know what the main question really is. Yuval hesitates but Natalie's query convinces him that the main question is about the lack of atmosphere on the moon.

It appears then that although the teacher asked a good challenge at the beginning of the discussion, he could not handle Yuval disputational style. In the hectic pace of a synchronous discussion, he rapidly lost control over the flow of the discussion. Instead of helping him to regulate learning processes in discussants, the persistence of previous interventions on the Argumentative Map probably impaired his functioning as a mediator in knowledge construction. The teacher's last intervention showed that he was unable to link students' thinking to the goal he set to himself in the discussion. It even appears that he mixed up the participants on which goal to pursue in the discussion as shown at the end of the discussion.

We present now a second discussion. In this discussion too, the moderator was a teacher. Three students, Ortal, Ariel, and Zvi participated in the discussion. Ariel gained the highest grades for almost all variables even before the activity, and stayed the same after it. Ortal and Zvi improved on correctness of their responses, integration and mental model. The outcomes are then "good". Let us see whether these gains are discernable in the guided discussion:

1) Teacher, Question, *is there day or night on the moon in the picture*?
2) Ariel, Opinion, *there's day in both pictures* (link to 1)
3) Ortal, Opinion, *you can't tell much from these pictures* (link to 1, opposition to 2)
4) Ariel, Question, *why*? (link to 3)
5) Ortal, Explanation, *because you can't see that there's light. The light can come from the camera* (link to 3, and 4)
6) Zvi, Explanation, it can also come from the earth
7) Teacher, Question, *why do you think so? What in the picture made you think so?* (support to 2)
8) Ariel, Explanation, *because there's light on all of the moon, (not including shadows from the mountains) so I don't think it's from the camera or from the earth* (link to 2 and 7, opposition arrows to 5)
9) Teacher, Question, *which camera?* (link to 5)
10) Ortal, Explanation, *the one they took the picture with* (link to 9)

The second discussion begins with a presentation of the main question in a broad and general manner, which receives different answers from the students. Ariel claims it is day, while Ortal claims that the pictures cannot help to decide. At turn 4, Ariel asks the reason for Ortal's standpoint; she gives her reason (the source of light is unknown) at turn 5. Zvi intervenes at turn 6 for the first time to suggest another possible source of light on the moon, the earth. At turn 7, the mediator begins referring to the interacting peers. She focuses on each of the discussants to clarify their points of view. Ariel is being asked to explain and elaborate his response (turn 8), and Ortal is being asked to explain hers—to which camera she is referring (turn 9). In the meantime, Ariel sustains his communication with Ortal as he links previous contributions (2 and 4) to his present one. Up to this stage, all students presented a reasoned argument. This quiet and reasoned opening seems to naturally lead the teacher to initiate a dialectical move:

11) Teacher, Question, *you say on the one hand that you can't see there's light, but on the other hand, you say that there's light that may be coming from the camera? What do you think, is there light or isn't there?* (link to 5)
12) Ariel, Opinion, *it's Ortal, you turned to her as a male* (link to 11)
13) Ortal, Explanation, *there's light, not day* (link to 7)
14) Teacher, Comment, *you're right, sorry* (link to 12)
15) Ariel, Opinion, *the sun* (link to 11)
16) Teacher, Question, *the light doesn't come from the camera's flash* (link to 10)
17) Zvi, Explanation, *but it can come from the earth* ['s light] *that comes from the sun* (link to 16)
18) Teacher, Question, *If you lighten a table with a lamp, will the table lighten the pen on the table?* (link to 17)
19) Ariel, Remark, *is that a question? Because I don't think so, and it's in the form of a question* (link to 16)
20) Zvi, Explanation, *no! OK, the earth does not lighten the moon* (link to 18)

We can see that the teacher initiates a dialectical move by raising a possible contradiction to Ortal's claims: on the one hand she says there is no light and on the other hand she mentions light from the camera (turn 11). It is highly probable that the teacher knew that there is no contradiction here but this was her way to focus on the relation between day and light. The discussion continues as a critical but friendly argumentative process: Ortal explains she meant that there is light but not day (turn 13). Ariel replies to the question on the source of light, and says to Ortal he doesn't think it comes from a camera (turn 15). The teacher agrees and provides Ortal with some information—the fact that the light doesn't come from a camera. Zvi, that seemingly feels neglected because his explanation has not been considered, reiterates his explanation that the source of light on the moon may be the earth. The teacher then refutes Zvi's argument by using an analogy between the sun and a lamp, between the earth and a table lightened by the lamp and between a pen on the table and the moon. This analogy convinces Zvi that he is wrong (turn 20). This episode exemplifies a long chain of reasoning full of explanations, challenges, refutations and agreements. The discussion is so harmonious that the teacher can refer to Ariel's remark in turn 19 on the form of the discussion without losing the thread of his moderation:

21) Teacher, Remark, *it's a remark, not a question* (link to 19)
22) Ariel, Remark, *so why you put it as a question and not as a remark?* (link to 21)
23) Teacher, Question, *Ortal, if I tell you that the light doesn't come from the camera, will you still think that you can't tell whether it's day or night?* (link to 10)

24) Ortal, Question, *so where does it come from?* (link to 21)
25) Teacher, Explanation, *a mistake, thanks for the correction* (link to 23)
26) Teacher, Question, *what do you think?* (link to 22)
27) Ortal, Opinion, *yes* (link to 23)
28) Ariel, Opinion, *from the sun, like it was in the last picture* (link to 24)
29) Teacher, Question, *and what would your answer be?* (link to 26)
30) Teacher, Question, *so why is the sky dark?* (link to 28)
31) Ortal, Opinion, *'cause it's night* (link to 29)
32) Ariel, Explanation, *as in the last class, I think that since there is nothing, then there's light only on objects* (link to 30)
33) Ortal, Opinion, *since space is empty* (link to 30)
34) Teacher, Question, *what makes you think it's night?* (link to 31)
35) Teacher, Question, *I'd like each of you to write a final answer, do you think that there's day or night on the moon in the picture, and to explain why*
36) Ariel, Opinion, *day—I think since there's nothing-vacuum, so there's light only on objects* (link to 35)
37) Ortal, Argument, *There's day on the moon, because you see light* (link to 35)
38) Zvi, *I agree with Ariel* (link to 35)

We can see that the teacher pays attention to each student's path of thinking and enters into a dialectic but dialogic/friendly move to capitalize on the discussants reasoned arguments to elaborate a more scientific account of the explanation to be given for interpreting the picture. In parallel, the teacher challenges Ariel's answer that there is day on the moon by asking why the sky is dark (turn 30). This challenge strengthens Ortal's argument that light does not come from the sun. Her reaction *'cause it's night* in turn 31 confirms this interpretation. Ariel's answer in turn 32 that *since there is nothing, then there's light only on objects* refutes Ortal's argument without being adversarial to her. So she elaborates in turn 33 on Ariel's argument (*since space is empty*). In a subtle way, she answers the teacher's challenge to Ariel, as if they are suddenly on the same side… Subsequently, when asked to give their final opinions they both agree that in the picture, there is day on the moon (turns 36 and 37). The teacher keeps being alert to any new idea and comments on it. She does not leave subjects unattended, unless they are addressed by one of the students themselves, and demands participation and reply. The fact that at turns 19, 20, 21, and 22 the teacher and Ariel interact concerning the correspondence between the ontology chosen with the Digalo tool and the function of the intervention in the discussion shows that the teacher and the students are able to reflect on the discussion as a whole in the heat of their argumentation; to some extent, they are aware of the overall goals of Kishurim, fostering dialectic and dialogic thinking. All students collaborate with the teacher as well as with each other (although Zvi is a bit aside).

Discussion

The present study has shown that combining mediated perspective taking and synchronous argumentation leads to conceptual change for the day/night cycle. Conceptual change is generally difficult to trigger and we argue that the meticulous design of the experiment is responsible for this important finding. The design was based on three decisions. First the students were explicitly scripted to participate in collaborative reasoning. Second, a CSCL tool was used to facilitate collaborative reasoning: Digalo's built-in constraints to choose among "argument", "claim", "explanation", etc., and to refer to previous interventions by supporting, opposing or simply linking through an arrow, were designed to enable collective argumentation. The third decision concerned the fact that students were provided with new perspectives materialized by different pictures taken from the moon.

Were those design decisions really responsible for the conceptual change? An orthodox answer based on experimental methods would be that the present study does not provide a clear response. Different groups with and without collaborative reasoning scripts, with and without CSCL tool for facilitating collaborative reasoning, and with or without pictures taken from the moon would have been necessary for such an orthodox answer. However, we did not include any comparison between groups or a control group, but intentionally adopted *quasi-experimental* methods according to a design research approach. We used inferential statistics to compare performances of a pre- and a post-test. We adopted a qualitative approach to complete the picture by analyzing the protocols of two guided discussions. This combination of multiple analyses is, we think, important to avoid the pitfalls of both quantitative and qualitative analyses in design research. On the one hand, qualitative research always uncovers phenomena that are difficult to generalize and on the other hand, quantitative analyses are reductionist, as they identify effects—correlations between variables, instead of phenomena. Multiple methods help identifying representative phenomena and going deep into their occurrence.

We evidenced conceptual change: first, we showed that 13 of the 32 students were able to explain properly the day night cycle although none of them could explain it before the experiment and that there was a positive effect as to the direction of this change. Second, we showed progression on the different facets of this change (*mental model, elaboration, simplicity,* and *integration towards universality of the day and night conception*). Interestingly, the only facet that did not uncover significant change was *correctness*, a fact that abounds in the direction of non-superficial progress. This overall deep progress is surprising since students had to overcome two obstacles. First, the students had to understand that the same scientific principle can be used to explain different phenomena: The students that could explain the day-night cycle on earth had difficulties in understanding that the same principle governs what happens on the moon. Explaining the day-night cycle on the moon through an eclipse of the earth was frequent at the beginning of discussions (7 out the 32 students). This tendency to stick to one familiar context naturally led to the second obstacle in learning the day and night cycle, geocentricity. 25 students thought that the day-night cycle exists only on earth. Some said that the moon is always dark, because "it appears only at night". Others said that there is no day-night cycle on Mars and on the moon because they are "outside of the earth's range". At the end of the experiment, most of these explanations were replaced by normative ones.

Besides the good news concerning conceptual change, the quantitative analysis provided quite a surprise—the fact for three out of the five variables, mental model, correctness and simplicity, showed that there was no effect from mediation during synchronous discussions. This finding is indeed surprising in the light of the review on the crucial role of mediation in learning scientific concepts. It suggests that moderation was not effective in facilitating collective reasoning.

The quantitative results suggest that pictures helped in integrating different contexts, leading to the elaboration of the scientific principle that stands behind the day-night cycle. The students compared the various environments with that of the earth and the mental voyage to other celestial environments enabled them to leave behind their egocentric understanding of the day-night cycle and to adopt a universal point of view. Naturally, their explanations turned to simpler and less context-bound.

This guided tour to different "worlds" seems very smooth to suggest that students inductively learn new concepts by mending their previous mental models to adapt to new evidence presented to them. However, it is well known that individuals are generally reluctant to change mental models when presented with challenging evidence (Chinn and Brewer 1998). The qualitative analyses of the protocols we analyzed could complete the unsharpened interpretation obtained through the quantitative analysis. As shown in both protocols, the students who were invited to engage in argumentation while confronted with pictures representing new perspectives brought forward different opinions and intertwined their different views with the different pictures. The students were then confronted with a double set of perspectives—astronomical/pictorial and inter-personal. This very combination led many students to conceptual learning: Ortal in the second discussion could capitalize on the teacher's challenge to Ariel to learn something. Zvi could learn from the teacher's refutation because the teacher referred to him and provided convincing evidence. The interpersonal perspective helped turn the astronomical perspective as relevant in the discussion space.

The second protocol also showed the role of the CSCL tool in this integration. With the help of the arrows, discussants referred to previous contributions even when non-contiguous (see for example Ariel's turn 8 in which he draws arrows of support to turn 2 and 4 and two arrows of opposition to turns 5 and 6). One of the students, Ariel again, reflected on a discourse category chosen by the teacher to challenge its match to the flow of the discussion. The second discussion could show another important function of the Digalo tool, the fact that the teacher could reflect on the discussion—a graphical map, and refer to previous intervention to instigate progress in the discussion. The new perspectives were materialized by different pictures taken from the moon that presented challenges to the students whose explanations had been geocentric so far.

Finally, the second protocol shows that the moderator was helpful in learning about the Day and Night cycle. She began with a presentation of the main question in a broad and general manner, and received different answers from the students. She focused on each of the discussants in order to clarify their points of view. She then initiated a dialectical move by raising a possible contradiction to the claims of one student. The students were not only responsive to her but interacted with each other. She refuted arguments, challenged explanations, and took into consideration all the opinions given in order to strengthen some of the arguments and challenge others, leading the students themselves to co-construct a scientific explanation of the Day on the moon. Thus, the mediator pays attention to each student's path of thinking and enters into a dialectic but dialogic/friendly move and capitalizes on the discussants reasoned arguments to elaborate a more scientific account of the explanation to be given for interpreting the picture. She keeps being alert to any new idea and comments on it. She does not leave subjects unattended, unless they are addressed by one of the students themselves, and demands participation and reply. This is a very complex endeavor.

As already mentioned, in spite of the overall impressive progresses in conceptual learning of the students who engaged in the Day and Night task, only 13 of the 32 students conceptual change occurred. Also, human moderation had no effect on conceptual learning. Why did the conceptual learning that occurred in the second protocol not occur in all discussions? Why was the success of the teacher in the second protocol not frequent? The first protocol gives a glimpse to these questions.

Is human mediation necessary in synchronous discussions?

The results of the quantitative analysis seem to give a clear and negative answer on the necessity of human mediation in synchronous discussions. But here also, the quantitative analysis sheds new insights on this issue. With Digalo, all previous interventions remain on the argumentative map. Such a characteristic may be beneficial but imposes high demands from the mediator who browses a huge amount of information. For example, in the first discussion, it was quite clear that Yuval's behavior was quite provocative. The teacher's challenge "why is the sky black?" is a good idea to initiate a dialectical process but is not well handled as it is displayed as a support to Yuval and an opposition to Natalie instead of being proposed as an opposition to both Yuval and Natalie (it thus exacerbates relations between Yuval and the other discussants). From that point onward, the discussion is neither dialectical nor dialogical: students do not collaborate and the discussion seems like a dispute almost exclusively between the teacher and Yuval in which the teacher neglects the other discussants. We suggest that the persistence of Yuval's irrelevant contributions on the map led the teacher to refer to them and to ignore the other discussants. However, what is needed to foster concept learning is exactly the contrary, to seek deep responses, to favor content-oriented moves. On the other hand the statistical findings we found on responsiveness suggest that beside personal and content-oriented interventions, mediators should adopt a wide rather than a specific style. This of course causes students' interventions to lessen. Consequently, it seems reasonable for the mediator to focus on all discussants, but preferably one at a time. This does not mean that organizational moves and in general moves for maintaining ground rules of critical thinking (encouraging participation, raising challenges, etc.) should be proscribed but rather used with parsimony. If organizational moves are too frequent, they may be followed by more responses, but these responses risk becoming superficial. Still, all types of mediation are necessary, for example organizational moves to remain focused on topic. The quality of a discussion needs then to find the right balance between content and organizational mediation. And indeed, the analysis of the two discussions above shows how different types of mediation are needed at different times and that they raise different responses from the students. Flexibility is needed from the mediator, a quick understanding of students' needs and responding to them, as happened in the second discussion. When flexibility is missing, and the mediator responds mostly to one student, as in the first example, the discussion risks getting stuck. Consensus between students may also become problematic as in the first discussion, and the mediator should help with elaborating understanding by challenging the collective. In case of disagreement (as in the second discussion), challenging each student separately is a possible mediation. Still, cooperation and discussion between students is a precious asset, and the teacher should try to support mutual questions and challenges. In summary, mediation of synchronous discussions is a difficult endeavor whose productivity depends on the teachers' mastery of different strategies, and on her flexibility and sensitiveness to students' needs here and now. Understandably, teachers in the study had difficulties in their mediation. Of course, a main source of difficulty is the fact that an unfamiliar tool was used for mediation. As it was their first time to work with students in this way, teachers were often slower than the students and sometimes did not focus on the main line of mediation. Current efforts are made to elaborate in-service teachers' programs for using synchronous discussions in classroom activity (Schwarz et al. 2009) and for mediating small group discussions.

In spite of the findings we obtained concerning the non-effectiveness of moderation of small group discussions, we do not pledge against teacher's guidance in small group work.

The second dialogue was an example in which the guidance was successful. We simply argue that this very complex task should be supported by a suitable environment, at least when the goal is challenging (e.g., learning a scientific concept). In a recent experiment in which teachers were trained to moderate synchronous Digalo discussions, teachers were found responsive to different scripts (Schwarz et al. 2009). In that study, discussions were about societal dilemmas rather than scientific concepts and the researchers did not measure learning gains but quality of discussions. These discrepancies with the present study being stressed, the quality of guided discussions was higher than that of unguided discussions. The two protocols we presented suggest the viability of facilitation of guided synchronous discussions, their desirability and at the same time, their high complexity. For this reason, our team has instigated the EC-funded Argunaut project aimed at providing various tools for the moderator in order to facilitate his moderation. First studies have shown the immense potential of these tools (Schwarz and Asterhan 2010).

Beyond the controversy concerning the necessity of human facilitation *during* synchronous discussions, the role of the teacher in the Day and Night task was varied: orchestration of brainstorming (step 2 of the Day and Night case) and of summing up discussions (step 6). Without those activities, the students would probably not have progressed in their understanding of the day and night cycle. More generally, the design of the task, the pictures, the stories, and the instructions were crucial for learning the Day and Night Cycle. In particular, the design was set to trigger conflicts and to solve them. Without this meticulous design, the engagement of the students would not have been so high, especially in unguided collective argumentation, where disengagement is so frequent. Students would not have been able to concentrate throughout the task. The use of different sub-tasks for teaching a single concept would not have been accumulated by the students in repetitive experiences towards the uncovering of critical details from the pictures. Thus, the background of our findings on the productivity of the combination between perspective taking and argumentation is a meticulous design. Without this design, combining unguided discussions with interpretation of pictures might have remained as unproductive as unexciting.

In conclusion, the ideas of critical reasoning and of collaboration were embedded in the design of the Day/Night Cycle activity. CSCL mediated collective argumentation and perspective taking through the use of pictures, were two practices we instigated to boost the above ideas among students. We showed that these activities triggered conceptual learning of the concept of the Day/Night Cycle, and conceptual change for a large part of the students. In the struggle that takes place in the schools in which we implement the Kishurim program, the positive results we obtained are important for convincing teachers, principals and parents that different practices and tools preserve what seems important for those who hesitate to change, the big scientific ideas. These ideas are also important for the proponents of change. The success in conveying them opens a space for discussion of how different stakeholders can evolve into a learning organization with goals that are become shared by all.

Finally, we showed that teachers play multiple roles in the environment we proposed, that their facilitation is needed in synchronous collaborative reasoning but that this enterprise is often too complex. However, they could not capitalize on the rich environment at their disposal to boost conceptual understanding during synchronous discussions. New tools and practices are necessary for improving the already very positive direction towards which science classrooms are heading with the use of such environments. Teachers took part in the design of the activity but remained peripheral in the implementation of the activity. The excellent results concerning the learning gains of the students announce a change that cannot be sustainable in other classes and without our help unless teachers become more central in the design of activities and in the moderation of CSCL-mediated collective argumentation. The teachers who participated in the present experiment may wish that the changes are established, but the researchers, designers, educators and teachers still have to learn as a community how to function as a learning community producing new tools and elaborating new practices for supporting students in science classrooms.

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Q6

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