Interweaving meaning generation in science with learning to learn together processes using Web 2.0 tools

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Abstract. The literature of the science education does not offer much data concerning meaning generation (MG) and learning to learn together (L2L2) processes. The objective of this paper is the study of how a group of students working with an on-line Platform, interact, collaborate and express themselves to generate meanings with regard to moving in 3d Newtonian spaces. The students create models of motions using 3d Juggler, a web-based half-baked microworld and communicate their ideas via the Platform's shared workspaces. The study was implemented with a small number of Greek students (four) of the 8th grade. The results of this study demonstrate that there is a relation between L2L2 processes and the creation of meanings in collectives as they use different web tools. After completing the scientific task (MG), the students of a Subgroup move to the Argumentation/Discussion tool to share with the other Subgroup the values of the parameters for which they attained their goal (L2L2 and MG processes). Distributed leadership and peer assessment are two of those L2L2 key aspects which dominate and influence students' MG processes.

Keywords: learning to learn together (L2L2) processes, meaning generation (MG), science, web-based tools, shared workspace tools

Introduction

In this paper, we study the meanings generated by the students as they worked with a Newtonian Physics microworld and how these meaning are mediated by the Metafora web Platform. The Metafora Platform (Dragon et al., 2012) is a completely web-based environment that is designed to support meaning generation processes and learning to learn together processes as groups of students -possibly in distance- collaboratively work on-line. Apart from a set of microworlds for mathematics and science, it also includes two WYSIWIS shared activity spaces (Avouris et al., 2003): the Planning Tool and the Discussion/Argumentation Tool. The Planning Tool is a shared workspace developed to support a group of students working together in planning their activities in advance, attributing roles and assigning tasks to the members of the group. LASAD is an on-line tool designed to support synchronous discussions between collaborative learners. The students (working individually or in groups), may communicate their ideas with their peers by adding textual contributions inside a shared workspace. The Metafora Platform also hosts Juggler (Kynigos, 2007), a 3d environment for building models of 3d motions and collisions inside a Newtonian space.

In using this web-based environment (Metafora Platform), we wanted to investigate what students learned with respect to the concepts investigated and how the Metafora Platform was used by the students in order to collaborate and communicate in this process. In addition, we wanted to study the process of meaning generation in the context of learning to learn together (L2L2). L2L2 is an important aspect of collaboration as it refers not only to what the students learn, but to how they learn to collaborate and communicate with others inside a group and jointly reflect on their work and their functioning as a team. We perceived distributed leadership, mutual engagement, peer assessment and group reflection (Wegerif et al., 2012) as the four key concepts for L2l2 and we sought for ways that these key concepts facilitated or enhanced the meaning generation process. That means that we looked for studied the process in which meaning generation triggered one of the four L2L2 elements and/or how the different elements of L2L2 might have influenced and shaped the process of meaning generation.

Within science education and mathematics, there have been attempts which focus on the concepts around which the students generate meanings (content) (Petridou et al., 2010; Jimoyiannis, 2010; Mikropoulos & Natsis, 2010; Jimoyiannis & Komis, 2001; Kynigos, 2008; Smyrnaiou & Dimitracopoulou, 2007). On the other side there are researches that have been focused on the L2L2 process. Wegerif et al. (2012) argue that L2L2 is not a simple process, but instead it requires a complex competence and it is independent of the content.

Several experiments have been conducted on the crucial aspects of L2L2. These experiments have showed that the collective learning process has the potential to proceed and evolve in parallel with the shared mental models of group members (taskwork mental models and teamwork mental models) within an open-ended challenge (Cooke et al., 2004). Other attempts have concluded that socio-metacognition (peer assessment) extends knowledge for group members and managing group learning requires knowledge of the learning styles and strategies of other members of the group. Distributed leadership is considered as an important aspect of L2L2; Gressick and Derry (2010) argue that the specialization of individuals in specific leadership roles within groups as well as the different forms of participation can be sources of distribution of leadership in online groups. Recent studies have referred to the mutual engagement of group learners that can be achieved through critical discussions, creative design and manipulation (Stahl, 2005; Wegerif & Yang, 2011).

In this research we are interested in collaborative meaning generation in Newtonian Physics through the Metafora web Platform. Our analysis focused on the description of instances where the process of meaning generation (MG) triggered (or not) one of the four L2L2 elements and the description of instances where the different elements of L2L2 seem to influence and shape the process of meaning generation (MG).

Web 2.0 in education and in science classroom practice

The case of the pedagogical use of Web 2.0 services such as blogs, wikis, social networking sites etc, has been an issue of thorough research by the educational community in recent and has led to a proliferation of pedagogical issues aimed at supporting and framing the computerization of the classroom. Common features of new services are the participatory characteristics, bi-directional communication between users, people's active role and effective participation, sharing content, mutual contribution, interaction and enhancement of users' creativity resulting in the development of social networks and learning communities (Angelaina & Jimoyiannis, 2012) which act as distributors of knowledge and expertise.

Social networking services (SNS) provide opportunities in the educational process such as school-developed projects at a classroom or school level, school cooperations, exchange-sharing digital educational material between members of educational communities, expanding the concept of school area and teaching hour (Alexander, 2006). The increasing use of Web 2.0 services in the education sector provides a fertile ground for the adoption of contemporary learning theories (Sampson, Karagiannidis & Kinshuk, 2010). Microlearning is a new theoretical construct associated with social networking tools-focusing on the student, who co-creates content using Web 2.0 tools through a process of powerful information sharing which therefore enables peer-to-peer learning (Lindner, 2006; Buchem & Hamelmann, 2010). However, use of these services is not always successful because it depends on many factors that can have a decisive influence on the whole process.

Nowadays there are various forms of collaborative learning platforms available whose aim is to support educational activities and challenge learners to participate in collaboratively building resources. Among these platforms, there are included environments reflected in the literature under the name eLearning 2.0 (Downes, 2005) or platforms of tele-education (Kalogiannakis et al., 2005) or CMS (Course Management System) (Psycharis, 2007) which allow teachers to exploit Web 2.0 applications in order to construct educational devices which will further expand collaborative learning in a setting of mutual engagement and contribution, providing this way deeper access into the cognitive issues under negotiation. An eLearning 2.0 device, according to the specific learning needs may be designed on a combination of specific features attributed to Web 2.0 applications: Forum (discussion, negotiation, argument), Wiki (collaborative writing), document management (sharing, storage), Blog (editorial and comment functionalities; document storage and sharing), etc. The advantage of this type of construction is that Web 2.0 tools are directly available, generally free and can easily be used in an educational setting (Williams and Jacobs, 2004; Caron, 2007). Moreover, these environments due to their rich and flexible functionality can be easily and totally controlled by students and/or teachers who can publish and exchange their products or artifacts in order to enhance reflective learning and promote metacognitive skills.

The continuing spread of the World Wide Web and mobile communication devices as well as their establishment as everyday prerequisite tools of communicative exchanges is changing the productive and design process of whole disciplines and industries. This change is mostly triggered by the vital importance of collaborative activity which will inevitably constitute the focus for the next phase of science, whose new research methods could have high intellectual and societal payoffs (Shneiderman, 2002; Bainbridge, 2007).

Understanding the dynamic functionality and communicative impact of these collaboration-centered, social-technical systems could lead to dramatic design improvements that accelerate their adoption and enhance efficient communication channels by highly raising their benefits. However, researchers will need to redefine and differently process the way of doing science (Shneiderman, 2008). The traditional sciences, Science 1.0, have brought astonishing advances from classical physics to modern physics. Nicolaus Copernicus revived the heliocentric model of the solar system described by Aristarchus of Samos. This was followed by Kepler's model which proposed that the planets follow elliptical orbits, with the Sun at one focus of the ellipse. Galileo also made use of experiments to validate or refute physical theories or laws and Isaac Newton published two successful physical theories/laws: Newton's laws of motion, which related to classical mechanics; and Newton's Law of Gravitation, which makes reference to the fundamental force of gravity. The beginning of the 20th century was the start of a revolution and innovation in the field of physics. Max Planck, Albert Einstein, Niels Bohr and others developed quantum theories to describe and explain various unexpected experimental results, by introducing the concept of discrete energy levels. Further developments led to the practical application of radar and the development and use of the atomic bomb. Science 1.0 will inevitably continue to be important and be seriously considered as a scientific paradigm but new kinds of science, Science 2.0, are needed to study the integrated interdisciplinary problems that are at the heart of socio-technical systems (Shneiderman, 2008).

The guiding strategies of Science 1.0 are still needed and will continue to feed and frame the functionalities of Science 2.0: hypothesis testing, predictive models, and the need for validity, replicability and generalizability. However, the Science 2.0 challenges cannot be studied adequately in laboratory conditions because controlled experiments don't capture the rich context or the hands-on mobility of Web 2.0 collaboration, where the interaction among variables undermines the validity of reductionist methods (Suchman, 1987).

Science 1.0 Great Scientists such as Galileo, Newton, Faraday, Maxwell, and Einstein produced key scientific equations that describe the relationships among gravity, electricity, magnetism, and light. By contrast, Science 2.0 researchers are adopting observational and case study methods as they collect quantitative and qualitative data to gain support for their hypotheses. Their work methods are in harmony with research initiatives on web science (Berners-Lee et al., 2006), creativity support tools, online education (Hiltz & Goldman, 2005), socially networked communities, etc. As Science 2.0 researchers our aim is to examine the benefits of the use of web-based tools such as Planning, Argumentation and Constructionist tool in science as an epistemic form of particular knowledge representation and focus on their potential to foster learning environments where students will efficiently collaborate with one another and be self-motivated by taking on increased responsibility for their own learning, in the context of meaning generation enhancement and elaboration on the metacognitive procedure as adopted by learners.

The 3d Juggler Microworld and Metafora System

3d "Juggler" is a web-based game-like half-baked microworld (Kynigos, 2007). As all half-baked microworlds, it is specifically designed so as to challenge students to make sense of how it works and change it (or parts of it) according to their own ideas on how it should work. Under this perspective, a large number of manipulable variables representing scientific concepts are integrated in this microworld (Smyrnaiou et al., 2012), aiming to offer students tools to explore and build their own models of 3d motions and collisions inside a Newtonian 3d space (Figure 1).

Juggler is basically a game. In order to play the game, the students need to first define the initial conditions for running the model that underpins the game. To do so, they have available eight sliders: the sphere mass, the shot azimuth, the shot altitude, the power (corresponds to initial speed), the gravity pull, the wind direction, the wind speed and the target size slider. By dynamically manipulating these sliders, the students attribute specific values to the corresponding physical quantities. As the same set of sliders appears for all three spheres (red, green and blue) that take part in the game, one physical quantity (e.g. the mass) could have different values for each one of the three spheres.

Once "Play" is pressed, the 3d Juggler game starts and the simulation of the model generated shows the three balls launching in the air according to the values set by the available sliders. If there is no wind (wind direction and wind speed sliders set to zero), and the gravitational pull is set to 9.81 m/sec^2, the spheres move in projectile motion trajectories. To observe the simulation of the model in 3d space, the students may use three different camera viewpoints.

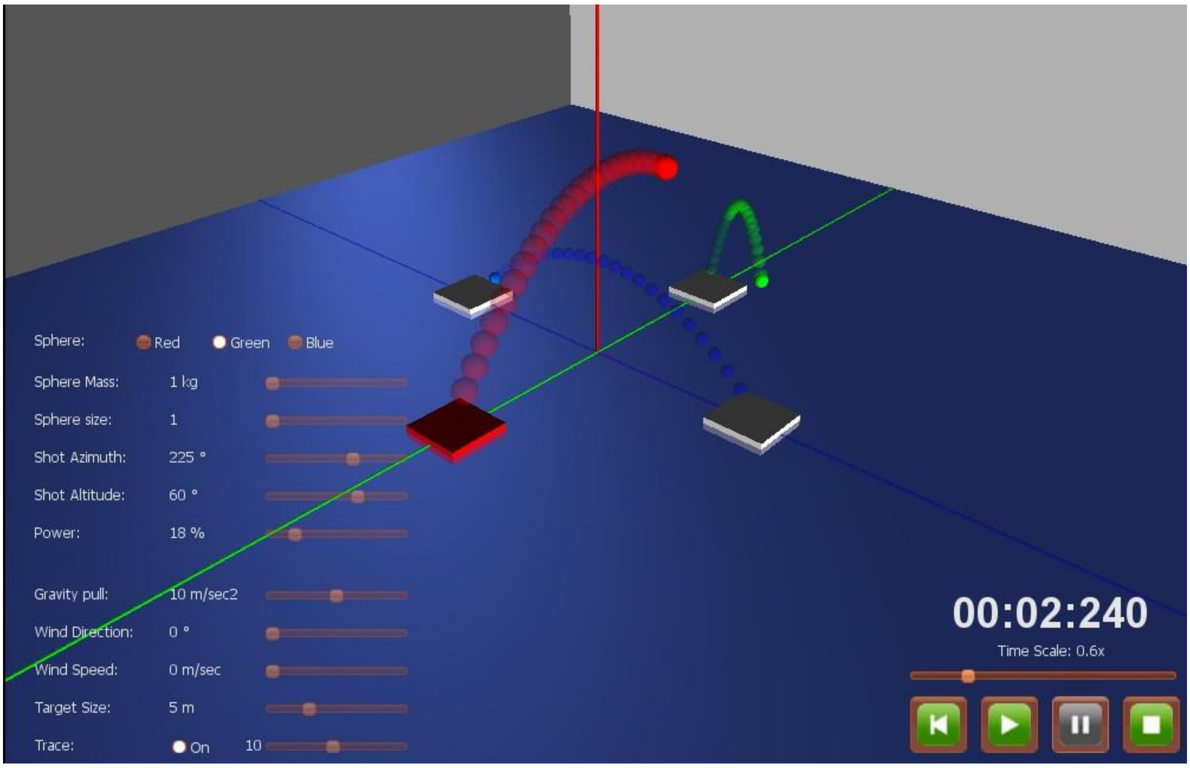

Figure 1. The 3d Juggler microworld

The 3d Juggler is integrated in the Metafora Platform (Dragon et al., submitted). The Metafora Platform is a web-based environment that is designed to support meaning generation processes and learning to learn together processes as groups of students collaboratively work on-line. Apart from a set of microworlds for mathematics and science, it also includes two shared workspaces: the Planning Tool and the Discussion-Argumentation Tool.

The LASAD Argumentation Tool

LASAD is an on-line tool designed to support synchronous discussions between collaborative learners. The students (working individually or in groups), may communicate their ideas with their peers by adding textual contributions inside a shared workspace. These contributions also have a graphical form (the text is typed inside predefined shapes the students select from a menu) and links can be added among them, connecting them to each other. Thus, LASAD can be used for the collaborative creation of maps -such as argumentation or concept maps- as well as for graphically representing and following an on-line discussion (discussion map).

According to the purposes for which LASAD will be used, special users (teachers or researchers) may customize the environment and create predefined sets of boxes inside which the students will type their contributions. To allow students to further tag their contributions, in each of those text boxes, special drop-down lists can be added, giving students the possibility to become more explicit with regard to the ideas they are offering.

The Planning Tool

The Planning Tool is a shared workspace developed to support a group of students working together in planning their activities in advance, attributing roles and assigning tasks to the members of the group. It encompasses a set of cards that correspond to Activity Stages, Activity Processes, Roles and Attitudes. For each card there is an icon depicting the meaning of the card, a text box to add comments and a set of available arrows to link the cards to each other. The members of the group place these cards on the Planning Tool's common workspace to form a Plan of actions to be taken so as to address a complex scientific or mathematical problem within the METAFORA Platform.

Enacting the Plan created could mean that the students work in different social orchestrations with the METAFORA Platform's microworlds or discuss in LASAD to coordinate their work with respect to the common goal (addressing the problem) and share their ideas with the rest of the group members. In any case, the Plan is an artefact that the students may use as a reference point and when they consider it suited, they are free to go back in order to revise it and change it according to their findings within the microworlds and the outcomes of their on-line discussions in LASAD.

Research Methodology

For the evaluation of the users' learning experience, we used a design-based research method (Cobb et al., 2003) which entailed the 'engineering' of tools and tasks, as well as the systematic study of the forms of learning that took place within the specific context defined by the means of supporting it.

Context and Participants

The study was performed at the 2nd Experimental Junior High School of Athens with four 7th grade students (2 girls and 2 boys). A team of researchers participated in data collection session, using a Research Protocol (worksheet) with the warm-up and the main challenges, a screen-capture software (Hypercam), a camera and tape-recorders. One researcher was occasionally moving the camera to all groups to capture the overall activity and other significant details as they occurred. Background data was also collected (e.g. students' worksheets and observational notes) and all audio-recordings were transcribed.

Activities

The students who participated in the Study were divided into two Subgroups. To become familiar with the three tools of the Metafora Platform - the LASAD, Planning tool and the 3d Juggler Microworld, we gave them a warm-up challenge. The challenge was to play with the 3d juggler microworld so that they "keep the blue and the green balls still and shoot the red ball vertically upwards". The warm up challenge also involved the creation of a common plan in Planning Tool to decide the actions to be done. Students were encouraged to discuss through LASAD any ideas about these actions.

Once familiarized with the three tools, we gave students the main challenge. We asked them to follow the same procedure (create a Plan, explore the situation within the microworld and discuss in LASAD) as they tried to make this time "the red ball hit the blue ball's base and stop moving".

Analysis

In analysing the data, we first looked for instances where meaning generation processes seemed to emerge as the students worked in Subgroups of two with the 3d Juggler microworld. In addition, we looked for learning to learn together processes as the two

Subgroups of students collaborated and used the two shared workspaces (LASAD and the Planning Tool) to communicate and evaluate their findings. Our interest lied in if and how these two kind of processes learning to learn together and meaning generation where connected to each other.

Scientific Meaning Making with working with the 3d Juggler Microworld

After the "warm-up" – familiarization activity, the students –forming a group of two subgroups - were given a new "task" to accomplish. As in 3d Juggler one may control the ballistic motion of three different balls starting from three different "bases", the students were asked to make each one of these balls hit another ball's base so as to gain game points. To address this challenge the students were asked to first create a Plan that would help them to organize their work towards the common goal.

The students of both Subgroups, however, instead of moving to the Planning Tool, went straight to the Juggler microworld so as to find a way to make one of the balls hit another ball's base. In this process, the students of Subgroup A built and experimented with an overall number of 25 different models. In this section of the paper, we attempt to highlight how their models evolved (their model road-map) and identify meaning generation processes in which the students engaged as they moved from creating one model, to changing it and creating another.

The students of Subgroup A create their first models and after doing so, they each time run the simulation to observe the outcome of their actions. After some time, however, it seems as if these try outs haven't helped them in extracting any reliable conclusions as for which physical variables they need to change or for what values to give to those quantities so as to make their ball hit the "base". Their confusion seems to stem from the fact that, in all these initial models, what they do is modifying simultaneously the values of too many sliders, failing in each case to interpret the result of their actions in the visual feedback generated. That means that up to this point students haven't incorporated to their exploration the basic experimental skill: "*every time I change one physical quantity, I need to see its effect on others*".

After being prompted by the researcher, the students read the Research Protocol more carefully[1] and notice that they need to give specific values to at least some of the variables. So, they set the values as follows: "Target size"=$2m^2$, "Gravity pull"=$10m/sec^2$, "Wind speed"=0m/sec and "Wind direction"=0^0. They also give "Shot Altitude" the value 0^0 and press "Play" to start the simulation.

Their attempt here was to give this variable the minimum possible value, trying to set the limits for this specific variable according to their own interpretation schema. This led to a new strategy which was to give the "Shot Azimuth" and "Shot Altitude" the typical values 360^0 and 90^0 respectively. Still, however, the students' experimentations seem not to align with a systematic inquiry process that entails forming hypothesis, building a model, simulating it, observing and interpreting the outcome and reconstructing it according to the visual feedback.

The researcher intervenes again in order to tell them "to keep the other two balls still (the blue and the green ball) so as to be able to see only the red ball moving". They give "Shot Azimuth" the minimum value of 0^0 and they press "Play". This is an attempt to set the

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[1] Extract from Research Protocol: It is given that there is no wind and the size of each ball's base is no bigger than 2m2 as well as that the activity takes place on the Earth's surface ($g=10m/s^2$)

variable's limits and observe the effects for these limits. Working in this direction, they keep “Shot Azimuth” with the minimum value of 0^0 and give "Shot Altitude" the intermediary value of 40^0. Out of this line, they give a random value to a variable they had not used so far (“Power”=17^0). This is probably because they either wanted to see how “Power” affects the ball's motion or because they were not focused any more on their effort to understand how the variables "Shot Altitude", "Shot Azimuth" work.

One of the students disregards the data given in the challenge's statement and gives "Wind direction" the value of 261^0, while the other student reminds him that it is a windless day as stated in the challenge. This points to the conclusion that the student making this remark has already realized what the variable "Wind direction" stands for. The group agrees on this remark and gives "Wind direction" the value 0^0.

After this small interval in which the students try out variables they haven’t worked with systematically so far (“Power” and “Wind Direction”), the go back working with “Shot Altitude” and “Shot Azimuth”. This opens a new strand in experimenting with “Shot Altitude” and the “Shot Azimuth”, as they turn things around and instead of keeping “Shot Azimuth” in its minimum value, they try out its maximum value which is 360^0. As it was the case before, they give "Shot Altitude" random values. An explanation for these actions could be again that they attempt to observe the effect of only one of the variables ("Shot Altitude"), as it takes random values, keeping, however, the other one to extreme values.

Realizing that they don't have the desirable results, they turn to the rest of the variables. They give "Power" the value 37% and "Mass" 7kg and press "Play" and viewing the simulation they come to the conclusion: "*The red ball doesn't move the way we want*". They have not realized that the motion doesn't depend on the mass of the balls so they alter its value. Although the students observed the ball's motion we notice that they do not seem to be concerned about the effect of the mass variable. The lack of some kind of comment or the fact that they accept not to alter mass's values shows some lack of attention or their limited ability to observe phenomena because they were not engaged in experimental procedures in the past or even because of their habit to follow specific instructions without evidence of critical thinking. The researcher intervenes and says "*Leave the mass as it was*" (they give “Mass” the value 2kg).

They go back to their initial steps giving both "Shot Azimuth" and "Shot Altitude" the minimum values (0^0). They may have lost focus because of their previous actions with regard to the variables “Mass”, “Wind direction” and “Power”. They are trying to recognize the variables/to find the variables' limits, but they now set both of them at the minimum value at the same time. The researcher intervenes and prompts them to alter the values of the quantities one at the time, keeping the rest unaltered. "*What are you planning to do? To alter the quantities one at the time? This means to give only Mass various values, then give only Shot Altitude various values, and so on…*" Researcher’s intervention is very significant in the modelling process.

After the researcher’s prompt the students go back again in their attempt to make sense of “Shot Altitude” and consecutively give it the values of 10^0, 38^0 and they "run" the corresponding models. The researcher asks "*What do you observe when you vary Shot Altitude's values?*". One of the students replies "*It (the ball) goes higher*" and once again gives random values to the variables so as to further explore this statement. They give “Shot Altitude” the value 33^0 and “Shot Azimuth” the value 100^0 and they press "Play". This attempt leads to some new conclusions. "*Shot Azimuth has to do with the direction*" says one of the students. The researcher prompts them: "*Why don't you change it (Shot Azimuth) again? Give it more values trying to* keep them aligned with their initial choices. They start changing “Shot

Azimuth" and give it the following values consequently 256^0, 234^0, 270^0 and they run the models. The researcher asks: "*What is it that you realize now that you change Shot Azimuth's values?*". The student answers "*Here, this is what we realize*" (he points with his finger showing that the direction of the ball's motion changes). Meaning generation in this case seems to be expressed through bodily interaction.

Continuing their attempts to achieve the goal, they give "Shot Azimuth" the value 303^0 and they observe that they are now closer to their goal. Little by little, they direct the red ball to the blue ball's base. However, in order for the red ball to hit the base it has to move in a lower altitude. To achieve this, they start diminishing the "Shot Altitude's" value to 19^0 and then 15^0 and run the models. "*It has to go a bit more to the…*" *(he means right)*, says one of the students. Therefore, they start altering the "Shot Azimuth" values to 309^0 and then 312^0 and run the models. The conceptualization of the 3-dimensional space seems to be difficult for the students as this is probably the first time they have used a 3d tool on a computer's screen.

Noticing that they have almost accomplished the desirable direction for the red ball, they now turn to the "Power" variable in order to come closer to the base. They give "Power" the value 28% and run the model. This action shows a more complex Subgroup thinking, since they manage to manipulate suitably not just two different variables ("Shot Azimuth" and "Shot Altitude"), but also a third one.

As they become more and more capable of manipulating those three variables at the same time, they start paying attention to more petty details and refine multiple times their models trying to be as much accurate as possible. The "camera" functionality aids them to accomplish their goal. They set it at the "Top" view and notice that the red ball does not hit right on the blue ball's base but it only touches it instead. They take advantage of the 3d tool's capacity and seize the opportunity they are offered to observe the motion from different points of view so as to make sure of the exact position of the ball. Making tiny adjustments they come to accomplish their goal.

In this excerpt, coming from students' interactions with the 3d Juggler web-based microworld, we attempted to identify episodes in which the students come to generate meanings about moving in 3d Newtonian space. The students collaboratively constructed multiple models -depicting initially intuitive ideas and as they proceeded more systematic ones- and they tested them through visual feedback, which is an intrinsic feature of the microworld. Their actions are revisited again and again as they built models to test their ideas, simulated them to observe the visual result, discussed about them and rebuilt them according to their understandings. Thus, it seems that the meaning generation processes that emerged as Subgroup A worked with 3d Juggler cannot be viewed as independent of the microworld's functionalities and the social configuration (two students working together in one Subgroup with the same microworld).

In the next excerpt, we will follow students' activities as they consecutively work in a different tool (LASAD and Planning Tool) and in a different social orchestration (two Subrgoups working together as members of the same Group). We will attempt to identify if and how learning to learn together processes appear and if and how these are related to the web tools used and the new social configuration.

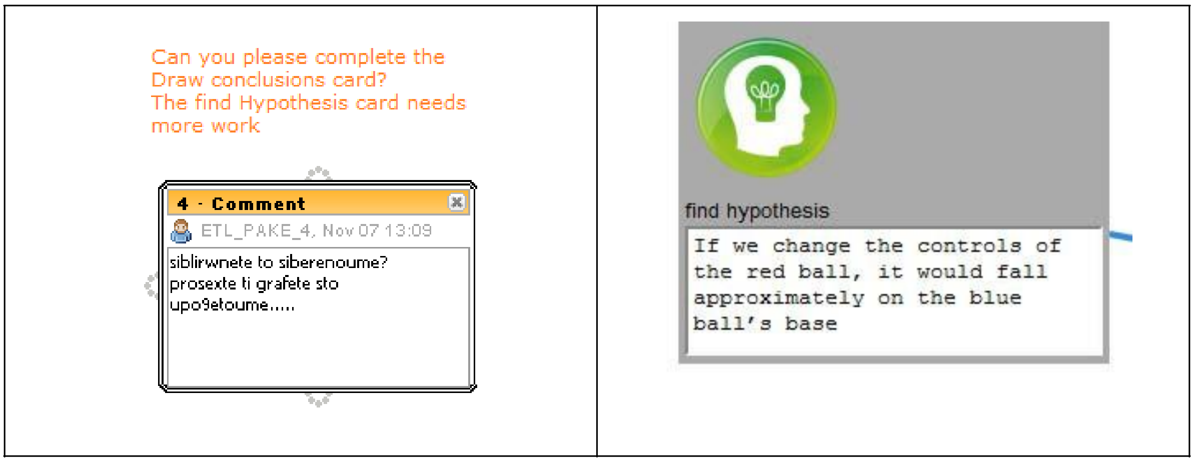

Figure 2. Evaluation in LASAD for Planning Tool contributions

Learning to learn together processes while working in shared workspaces

Evaluating group learning

Shifting attention from the task to the process of implementation

In this section we focus on the part in which the students working in as a Group evaluate the work they have done. This evaluation was expressed in a LASAD contribution added by Subgroup B and referred to the common work done by the two Subgroups in the Planning Tool (see Figure 2.)

In the picture above we can see that the contribution of Subgroup B in LASAD has a dual focus: a) the evaluation of the work of Subgroup A in the Planning tool and especially the content of the "Find Hypothesis" card and b) to prompt for the orientation of the work in the Planning Tool (i.e. complete the "Draw Conclusions" card). Both aspects of Subgroup B's contribution in LASAD are expressed in the style of teacher evaluation: *"pay attention to this"* or *"why don't you do that"* (i.e. complete the "Draw Conclusions" card). The characteristic of this evaluation is that it is done from the point of view of someone who evaluates the work someone else has done (the other Subgroup) and not the common work of the Group. This style of evaluation seems to be grounded on the mode of intragroup collaboration where each group works separately without agreement on a common plan.

Specifically, Subgroup A, instead of following the task description to start from the Planning Tool, they skipped this step and they went directly to the 3d Juggler microworld. At the same time Subgroup B was struggling with the Planning Tool. This method of work resulted in Subgroup A coming up with the solution for the task before Subgroup B. When Subgroup B asked them in a face to face communication to explain how they had found the solution, Subgroup A used the Planning Tool to report their actions and help Subgroup B to generate scientific meanings.

In this context, where Subgroup A first completes the task and then uses the Planning Tool as a medium for retrospective reporting, Subgroup B does not lay back waiting for Subgroup A to complete the work. On the contrary, Subgroup B adopts an active managerial role. This role seems to be based on the following assumptions: a) that the task is not completed with the 3d Juggler[2] but with the Plan in the Planning Tool, b) that their contribution should focus more on how group-work should be refined (pay attention to the hypothesis card) and organised (complete the "Draw Conclusions" card). So we observe a shift from the actual task to the process of performing and implementing the task. Subgroup B's evaluation shows that students know what has to be done and present it with the authority observed normally in the relationship between teacher and student and not between co-workers.

It becomes apparent that the mode of collaboration between the two Subgroups brought them in a situation where one Subgroup completed part of the task (in 3d Juggler) and should find a way to update the other Subgroup about what had been done. The use of the Planning Tool at this point shaped a learning situation where the process of completing the task in 3d Juggler became a sharable object between the two Subgroups. This shared object allowed Subgroup B not only to understand what the others had done, but also to evaluate the results of their work and make managerial suggestions in LASAD for refinement (complete the "Draw Conclusion" card) and reflection ("Find Hypothesis" card). As we will show in the next section, Subgroup A's response entails an evaluation of Subgroup B's contributions in the Group work and a prompt for different type of contribution and engagement.

Evaluation as a trigger for reconsidering contributions in teamwork

In this section, we will focus on Subgroup A's response to the comment of Subgroup B. As depicted in Figure 3, Subgroup A completed the "Draw conclusion" card in the Planning Tool and then returned to LASAD to report that they followed Subgroup B's suggestion and they prompted them to check out the Plan and offer their ideas for the specific card. In Subgroup A's response we observe the following characteristics: a) they report on their actions and b) they prompt Subgroup B for specific action at the Planning Tool. With the first part of their response, Subgroup A shows that they followed Subgroup B's suggestion, which is an implicit acknowledgement of the usefulness of their suggestion. On the other hand, there is no reference to the corrections suggested for the "Find Hypothesis" card.

Figure 3. Subgroup A's response: work in the planning tool and prompt for contribution

[2] Students when engaged with microworlds usually feel that they have completed the task when they have completed their work with the microworld (i.e. make the balls hit each other's base).

Actually, Subgroup A did not change this card, which implies that the comment was not accepted by the Subgroup. So it appears that there is an evaluation of the suggestions which are expressed in the reported actions (we follow the suggestions we consider useful or we can understand) but there is no evidence for negotiating or discussing the suggestions which are not followed.

The second part of the contribution Subgroup A made in LASAD is an attempt to re-direct the work of Subgroup B in the common task. Thus, Subgroup A, suggests that Subgroup B, should be engaged in some ground work –offer ideas for the "Draw Conclusions" card-which is different from the managerial comments made earlier by Subgroup B. This comment entails an implicit evaluation for the contribution of Subgroup B, which up to this phase had focused on telling to Subgroup A what to do instead of doing it or helping them out to do it. Hence this comment appears to be more than a prompt for work if we consider that Subgroup A's contribution was mainly related with the task per se, whereas Subgroup B's contribution was mainly related with reflecting and evaluating the work done.

Distributed leadership: using evaluation and action as a basis for claiming leadership

Leadership is not something that was agreed between the two Subgroups. On the contrary, it was claimed interchangeably by both Subgroups in several occasions. So, the question here is: *"what is the source of power that supports claim of leadership between the two groups?"*.

In the course of this task Subgroup A, seems to be the leader as they take the initiative not to follow the researchers' instructions and start working with the 3d Juggler microworld to accomplish the task. This was an action not agreed between the two collaborating Subgroups but influenced the course of Group work and offered the ground upon which the remaining work was based. At the same time, Subgroup B was trying to work on the Planning Tool where they discussed which cards to use and how they were going to experiment. The results of the work done by Subgroup A however, lead them to change the route of their work, leave the Plan they were trying to make and try out the solution offered by Subgroup A in the 3d Juggler microworld. From the perspective of intragroup collaboration, Subgroup A leads whereas Subgroup B follows. The source of power upon which Subgroup A grounds their leadership, is that Subgroup A has been effective in their experimentation with the 3d juggler. This was a crucial moment for intragroup collaboration because it forced Subgroup B to stop what they were doing. The reason for this is that Subgroup B was engaged in planning how to solve the 3d Juggler problem when Subgroup A came up with the solution. So, at this point the question with which Subgroup A was faced was *"Is there any point in continuing with the plan on how to resolve the 3d juggler problem when the problem is already resolved?"*. The decision taken by both Subgroups was related with what they perceived as a completed task (when the Plan and the 3d Juggler model is constructed). This decision also showed a good distribution of resources: those who solved the problem were the most suitable to explain the process of problem solving.

After Subgroup B tried out the solution suggested by Subgroup A in 3d Juggler, they returned to the Planning Tool and took the lead by directing Subgroup A towards the next actions in the Planning Tool. In this case, the evaluation of Subgroup's A solution (L2L2 processes) seems to offer to Subgroup B the power to lead. In this balance of power, Subgroup A follows the suggestions of Subgroup B and attempts to take the lead again prompting Subgroup B to contribute to the actual task (offer ideas for the conclusions) suggesting at the same time a change in their roles (leader vs follower). In this case, the source of power appears to be mainly action that provides the knowledge for what should be the next step: "we did our part and this allows us to pinpoint where you can contribute".

An interesting observation here is that although leadership is not discussed, negotiated or agreed between the Subgroups but taken upon grounded claim interchangeably, the work seems to proceed smoothly. Specifically, it appears that each Subgroup when it takes the lead builds on the actions of the previous leader, i.e. it does not ignore or cancel what has been done so far- and is following the suggestions made by the leader without questioning them.

In these two excerpts, the students seem to engage in L2L2 processes, such as evaluating the work done by others (peer assessment) and evaluating the Group's work towards achieving the common goal. These processes rise as the students move from 3d Juggler to the shared workspaces and start working as one Group instead of two Subgroups which was the case up to that point. This change of workspace and change of social configuration also evokes issues regarding who has the leadership of the Group. Distributed leadership is a learning to learn together process in which the students seem to embrace as they take the lead interchangeably, even though they haven't explicitly discussed with each other that this should be the way to work as a Group.

In the following section, we try to move away from the learning to learn together (l2l2) processes in which the students engage as they work with the shared workspaces (LASAD and Planning Tool). Taking a look at the exact same excerpt as in this section, we attempt to focus on the "learning to learn together something" aspect. Meaning generation with regard to moving in 3d space was viewed as a process linked to the use of the 3d Juggler microworld as the students worked in Subgroups of two. In this next section we seek to highlight if and how the collaboration among the two Subgroups as they worked in LASAD and the Planning Tool had an impact on their scientific meaning making.

Learning to learn together "something" (science) processes

After hitting the blue ball's base with the red ball, the students of Subgroup B move to LASAD (see Extract in Table 1) to share with Subgroup A the values of the parameters for which they attained their goal. Subgroup A just a few minutes ago had done the exact same thing (Figure 4).

Table 1. Extract 1: Learning to learn together

Extract 1 (LASAD)
Contribution no 2 - Subgroup A: In Shot Azimuth give 315° and in Shot Altitude 0°. Then they change the weight. ***Contribution no 3 - Subgroup B:*** Shot Azimuth 316°, Shot Altitude 21°, Power 25% ***Contribution no 4 - Subgroup A:*** Can you complete the "Draw Conclusions" card? [at their Plan in the Planning Tool]. Be careful what you write in "Find Hypotheses" card [at their Plan in the Planning Tool]. ***Contribution no 5 - Subgroup B:*** With what we did, it came out correct. As for the weight we made it 2kg. [answer to the Juggler values] ***Contribution no 9 - Subgroup B:*** We completed the "Draw Conclusions" card [at their Plan in the Planning Tool].… it seems you have to look at what we have written and tell us your ideas as well

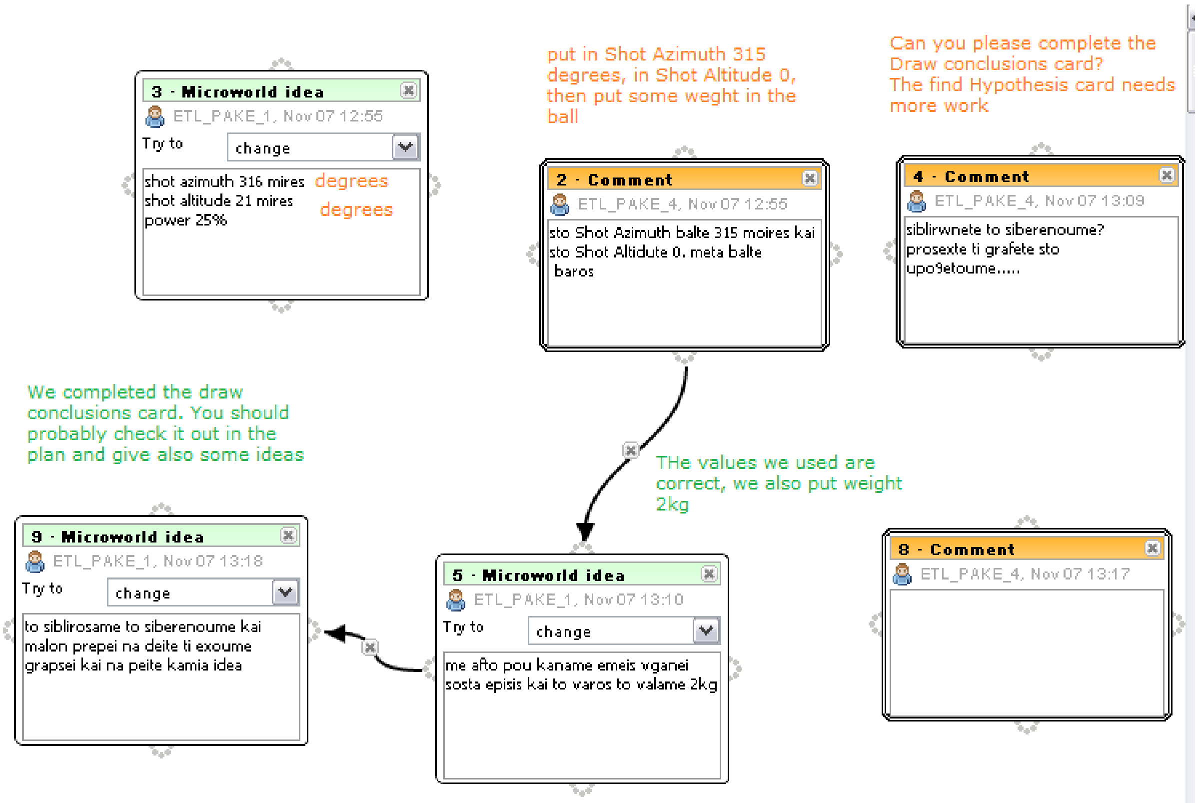

Figure 4. The map two Subgroups of students created in the LASAD Discussion Tool

Although the students of both Subgroups had been working with the Juggler microworld for quite sometime, and they always had at their disposal the LASAD map to share their ideas, they preferred to make public their models only after they had managed to hit the racket. Specifically, the students of Subgroup B, created and tested 18 different models before making the ball hit the racket, while the students of Subgroup A had created more than 25. All this time, both Subgroups chose not to ask for any help from the other Subgroup or post in LASAD any indications about the outcome of their explorations. Even when they came to exclude certain physical quantities (like the ball's ”Size” or the “Wind direction”) from the set of parameters they needed to manipulate so as to make the ball hit the racket, they didn't inform their peers through LASAD so as to save them sometime or help them with their own experimentations. For all this time, the two Subgroups chose to work independently, exchanging no information with regard to their findings.

What is interesting in the stance the two Subgroups adopt, is that they both started working in this session as one Group with the mission to collaboratively address the challenge given to them within the 3d Juggler microworld. For this purpose, they had created a Planning Tool map to define step-by-step the course of action they would take as a Group so as to achieve this goal. Consequently, they work in the 3d Juggler microworld as two separate Subgroups but have at their disposal the LASAD Discussion Tool so as to communicate and coordinate their work as a Group. It seems, however, that the students, when moving to the 3d Juggler and just after that to LASAD, they once again do not consider themselves as one Group of students struggling to achieve one common goal, but as two separate Subgroups showing even some kind of rivalry to each other.

The students of Subgroup B, having in mind the Plan they had created before, take the initiative to ask the students of Subgroup A to move to the Planning Tool and report in the “Draw Conclusions” card the outcomes of their explorations. At this point (Contribution no

4), it seems that the students of Subgroup B take things into their hands with respect to the Group's functioning and suggest to Subgroup A to go back to the common Plan (Figure 5) so as to inform and update it with their findings (L2L2 processes).

Taking up even more leadership responsibilities, they ask the Subgroup A students to rethink about their contributions in the "Find Hypotheses" card in their common Plan (Contribution no 4). This indicates that these students, apart from Distributed Leadership activities they have also engaged in Peer Assessment as they evaluate what the Subgroup A students have added in the "Find Hypotheses" card as inadequate or incorrect with respect to the Group's explorations and findings (L2L2 and MG processes).

This is an indication that the students of Subgroup B engage in learning to learn together processes (distributed leadership and peer assessment) that are not disconnected from the meaning generation processes in which they engaged when they worked with the microworld. Having constructed meanings with regard to how the ball should move in the 3d Newtonian space and the scientific concepts that play a role in manipulating this motion, the students of Subgroup B evaluate the model Subgroup A has created. Thus, they ask the students of Subgroup A to make changes to their model with regard to "Shot Azimuth", "Shot Altitude" and the "Mass" (Contribution no 2).

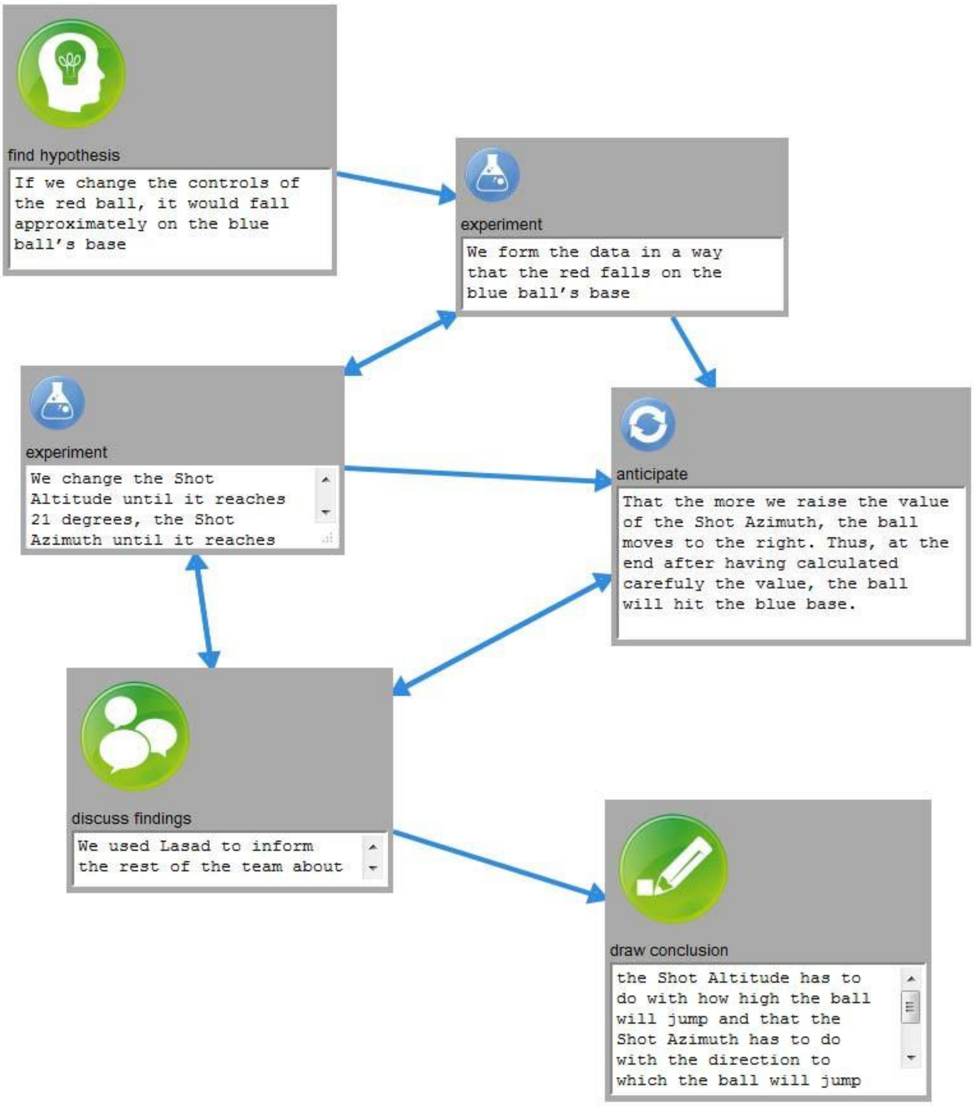

Figure 5. The common Plan the Groups of the students created in the Planning Tool

Subsequently, going further in evaluating the work Subgroup A has done in the Planning Tool, they ask them two things: a) to change the "Find Hypotheses" card and b) add text to the "Draw Conclusions" card. Again, Subgroup's B prompts to Subgroup A are not independent of the meanings they constructed when working with the 3d Juggler. They find the "Find Hypothesis" text inaccurate as it doesn't depict the hypotheses they formed to make sense of how the ball moves in 3d space.

In this excerpt, coming from the students' interactions with LASAD and the Planning Tool, we attempted to describe if and how the learning to learn together processes -that we also identified in the previous section- were related to the meaning generation processes in which the students engaged as they worked with the 3d Juggler microworld.

Highlighting the students' contributions in LASAD and the Planning Tool, we observe that two Subgroups engage in learning to learn together processes that are not unrelated to what they are learning about. Having generated meanings on how the ball should move, the students use their understandings to evaluate the findings the other Subgroup reports and push towards correcting Planning Tool cards according to these understandings. This puts them in a leading position which they at least temporarily maintain.

Conclusions

The two Subgroups of students, both members of a common Group, are asked to work together so as to make in the 3d Juggler web-based microworld "the red ball hit the blue ball's base and stop its motion right there". They start with creating a Plan as a Group (using a planning web-based tool) so as to define their course of action and consequently work separately (as two Subgroups) with the 3d Juggler microworld, having also at their disposal at all times a shared LASAD map (using a discussion web-based tool) where they may discuss their ideas and findings.

The students of both Subgroups, however, instead of going to the Planning Tool and create a detailed Plan, they move quite soon to the 3d Juggler microworld so as to find a way to make one of the balls hit another ball's base. In this process, the students of Subgroup A built and experimented with an overall number of 25 different models (MG processes) while the students of Subgroup B built and experimented with an overall number of 18 different models (MG processes). As they worked with the microworld, the two Subgroups chose not to communicate their ideas via the shared workspaces they had available (LASAD and Planning Tool). Thus, during this phase, in which meaning generation with regard to motion in 3d space was quite extended, the students worked in two separate Subgroups, showing no disposition to collaborate with each other.

After completing the scientific task (MG), the students of one of the Subgroups move to LASAD to share with the other Subgroup the values of the parameters for which they attained their goal (L2L2 and MG processes). In addition, they use the LASAD shared workspace to communicate with regard to what needs to be changed in their Planning Tool map and to what needs to be done to fulfill their goal and accomplish the task. Thus, in this phase, the students consider themselves as two separate Subgroups working together towards a common goal.

In this process, the students engage in learning to learn processes which seem not to be independent of what they were learning about. The students evaluated the other Subgroup's model and Planning Tool contributions, after having generated meanings regarding the motion of the ball in 3d space. Thus, the assessment and the distributed leadership included in the learning to learn processes appeared to be interwoven with the meaning generation process and not independent of it.

The study has certain limitations that need to be taken into account when considering its contribution to L2L2 and MG processes using web-based and shared workspace tools. These limitations of the work presented are due to the conditions of data collection: pilot study and design-based research. That means 1/the number of participated students was small and 2/the design of the web-based tools and scenarios continue. In addition, we avoided bringing other information than this provided by the activities themselves, with the web-based tools. Future studies with more students, different orchestration of groups, and final version of tools and scenarios will make it possible to specify what might be the relation between L2L2 and MG processes.

Acknowledgements

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