Chapter 11
Developing Technological and Pedagogical Affordances to Support the Collaborative Process of Inquiry-Based Science Education

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1 Introduction

The understanding of "learning to learn together" (L2L2) is inspired by the real working lives of professionals having to work together with others in teams to solve complex problems and make decisions. For example, when, in April 2010, an explosion in the Gulf of Mexico caused a flow of oil, BP responded by assembling a team of experts to find a solution. This team was not colocated and so they had to work together sharing ideas and co-constructing plans of action supported by web-mediated communication tools. Distributed teams of experts working together to solve problems and inquire into issues are increasingly common in the knowledge economy. Computer-supported collaborative teamwork of this kind is not only a response to time-sensitive crises but also the main means by which new knowledge is constructed in the sciences. However, current education systems do little to equip children and young people with the complex competence of problem solving and learning together with others online. In the case of the 2010 oil spill, the team of experts failed to come up with a successful solution until the oil had flowed for three months, doing great damage to the environment. A lack of technical knowledge may have contributed to this failure, but it is also possible that a lack of knowledge about and experience of learning together effectively may have contributed to this delay. There has been some research on ways to teach for learning how to learn (L2L), which is often referred to as the most important knowledge age skill as it equips people to adapt flexibly in a time of rapid change. However, there has been little research on how to teach for the skills involved in L2L2, which is possibly

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even more important for surviving and thriving in the knowledge age since most knowledge work is conducted by teams working together rather than by individuals working alone.

As a response to this education and research need, a web-based learning environment has been developed to support collaborative inquiry-based learning in science stimulated by complex real-world questions. It has been developed and trialled in secondary science classrooms but we think that it also has the potential to support learning beyond the classroom. Social networking sites such as Facebook have proved popular but are not equipped with tools that can help groups engage in inquiry-based learning together. The planning tool developed in our project is web based and could support any group in an inquiry into any topic.

This chapter focuses on the development, implementation and evaluation of the web-based learning environment called Metafora[1] which develops a planning and reflection tool using a visual language representing the key components and features required for L2L2 in the context of solving a complex science problem.

Section 11.1 reviews the literature around two axes: (a) inquiry science processes and (b) L2L2 skills. Section 11.2 presents the Metafora platform. Section 11.3 reports the design-based research carried out in secondary schools in Spain in order to gain an understanding about the Metafora's technological and pedagogical affordances to support students' awareness of the key aspects of learning together and the key scientific inquiry processes. Finally, Sect. 11.4 discusses the findings and conclusions of our study.

2 Key Stages of a Dialogic Inquiry Process in Science

2.1 Approaches to Inquiry Processes

Learning occurs through a social process of inquiry (Dewey 1938). There are different ways to approach inquiry. Reflective inquiry seeks to draw attention on the coupling of metacognition and inquiry in the context of solving open-ended, ill-structured investigations in science (Kyza and Edelson 2003). The name "reflective inquiry" thus has a double meaning, and deliberately so. The first meaning is reflection as in thinking seriously about something. The second meaning is to use a mirror to reflect an image of oneself while working (Keating et al. 1996). In the scientific inquiry-based learning context, de Jong (2006) states that children have difficulties in solving general metacognitive problems and fail to regulate their behaviour or plan effectively. Moreover, shared inquiry requires a commitment to open up both literally and metaphorically the necessary time and spaces to try things out, to play with variations, to probe the possibilities for enhancing motivation and learning

[1] "Metafora"—Learning to learn together: A visual language for social orchestration of educational activities. FP7-ICT-2009.4.2 Technology Enhanced Learning, contract no. 257872.

and to take risks in entering new territory (Thomas and Oldfather 1995). Brown and Campione (1996) recognise that participation in an extended process of shared inquiry fosters children's ability to ask complex questions.

The US National Research Council (2000, in Grandy and Duschl 2007, p. 156) strengthened its definition of dialogical processes of inquiry beyond conceptual learning goals and decided to add the following dialogic features to inquiry learning process:

- Responds to criticisms from others.
- Formulates appropriate criticisms of others.
- Engages in criticism of own explanations.
- Reflects on alternative explanations and not have a unique resolution.

The dialogic process of inquiry can also cultivate learners' scientific thinking skills. It can help to overcome the disjunction between newcomer and expert worldviews (Clancey 1989). For example, in a study of physicists' mental models, Roschelle and Greeno (1987) revealed that experts reasoned about physical situations by creating two parallel mental models, one that represented objects corresponding to physical reality and the other that represented objects corresponding to abstract scientific principles. Physicists developed their analyses of physical situations by comparing the predictions of both mental models. The gap between students' and scientists' worldviews is not localized at the level of "concepts" and "misconceptions", but extends throughout the fabric of thinking—including perception, focus of attention, descriptions of the world, practices of interactions with the world, forms of valid knowledge and values.

2.2 Stages of Inquiry Processes

Different theoretical perspectives have approached learning as a process of inquiry and different models of inquiry have been researched and defined. The main objectives of this section are to review, compare and synthesize five relevant models of inquiry as a theoretical base to construct the key stages and variables of the Metafora inquiry process and to design a superset of the visual language to support L2L2 in science.

Table 11.1 summarizes the comparison of the next five inquiry models: Anastopoulou et al. (2009), Shimoda et al. (2002), Schwartz et al. (1999), Llewelyn (2002), Hakkarainen (2003, 2010). The comparison is made in relation to what phases or stages of the inquiry process each model emphasizes and which is the main focus of each model.

As a result of the comparison and synthesization of these five models, we found a general agreement on the importance of six key stages that were shared. These six stages are presented in Table 11.2.

These six stages are introduced in the design of the visual language of the Metafora platform, and through pedagogy, they are taught to the students. The main aim

Table 11.1 An abstract description of the present five perspectives of inquiry process

	Anastopoulou et al. 2009	Shimoda et al. 2002	Schwartz et al. 1999	Llewelyn 2002	Hakkarainen 2010
Phases/stages	Find my topic Decide my inquiry question or hypothesis Plan my methods, equipment and action Collective my evidence Analyse and represent my evidence My conclusion Share and discuss my inquiry Reflect on my progress	Hypothesis Investigate Analyse Synthesize Extend Question and theorise	The challenge Generate ideas Multiple perspectives Research and revise Test your mettle Go public Look ahead and reflect back	Introducing a topic Assessing prior knowledge Providing exploration Raising and revising questions Brainstorming solutions Carrying out a plan Collecting data Organising data Communicating results Comparing new knowledge to prior knowledge Applying knowledge to new situation Stating a new question to investigate	
Focus of the framework	This is a personal inquiry framework. It enables the students to flexibly sequence the activities	This is a generic inquiry circle, named as a sequence of goals to be pursued by learners	This circle is implemented as a technology template to guide learners through case-, problem-, project-based learning	This circle is a constructivist inquiry cycle from a more detailed inquiry approach	This circle represents a sustained process of advancing and building knowledge

of this pedagogy is to help students to define and be aware of the collaborative processes that the team work has to develop in order to solve the science problem.

For each phase, a set of visual language is proposed. This visual language refers to main processes that students might develop in order to fulfil the objective of each stage. In Fig. 11.1, we represent the main stages (*big green squares*) and processes (*small blue squares*) presented to the students in order to solve the science problem. The basic stages students could follow to solve the problem are represented in Fig. 11.1. However, students were strongly encouraged to design their own team inquiry process and should consider the processes to solve the problem.

Table 11.2 Summary of the overlapped key stages between frameworks

Overlapped stages	Anastopoulou et al. 2009	Shimoda et al. 2002	Schwartz et al. 1999	Llewelyn 2002	Hakkarainen 2010
First phase explore and define a question/topic	Find a topic Decide my inquiry question or hypothesis	Hypothesize	The challenge Generate ideas Multiple perspectives	Introducing a topic Assessing prior knowledge Providing exploration Raising and revising questions	Set up the context Present the problem Develop deepening problem
Second phase to create a solution/hypothesis to the problem	Plan my methods, equipment and actions	Investigate	Research and revise	Brainstorming solutions	Create working theory New theory
Third phase to test a solution and refine the solution	Collect my evidence	Investigate	Test your mettle	Carrying out a plan Collecting data	Critical evaluation
Fourth phase to analyse the results or outcome of the tested solution	Analyse and represent my evidence	Analyse	–	Organising data	Critical evaluation
Fifth phase to make conclusion and present to the public	My conclusion	Synthesize	Go public	Communicating results	Not applicable, because this framework views the whole process through distributed expertise
Sixth phase to reflect and make transfer	Share and discuss my inquiry Reflect on my progresses	Extend Question and theorise	Look ahead and reflect back	Comparing new knowledge to prior knowledge Applying knowledge to new situation Stating a new question to investigate	Critical evaluation Searching Deepening into the knowledge

3 Key Aspects of Learning to Learn Together

L2L is often referred to as the most important knowledge age skill since it equips people to adapt flexibly in a time of rapid change. However, we argue that the reality of Internet-mediated learning is more about L2L2 with others than about learn-

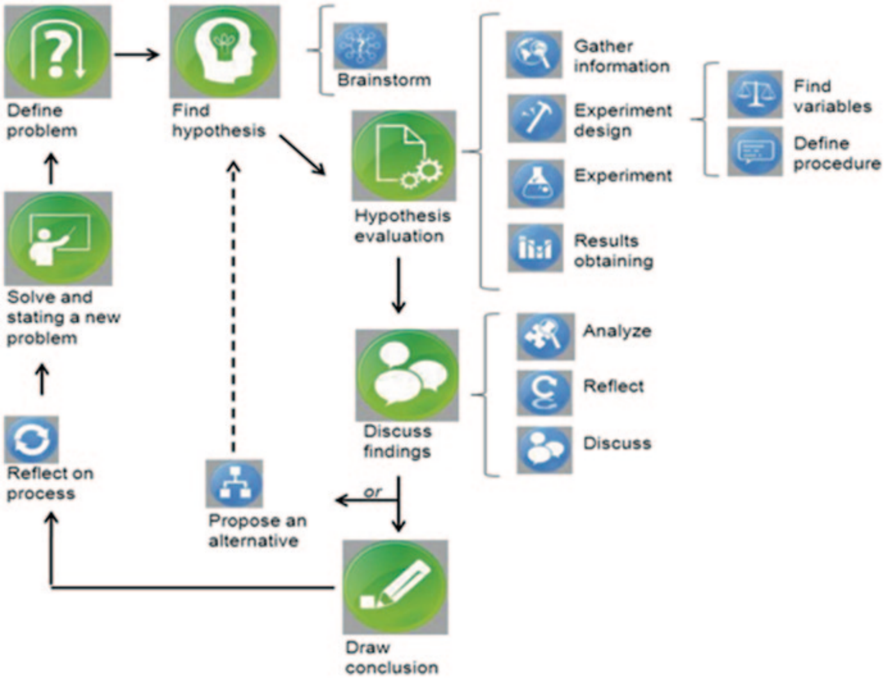


Fig. 11.1 The main visual language icons developed in the Metafora project

ing to learn as an individual. Much knowledge work is conducted by teams and not only by individuals. L2L2 goes beyond L2L because it combines the dimension of task management (how to organise complex inquiries with multiple stages and strands) with the dimension of social relationships (working with attitudes, expectations and identities in order to participate constructively in learning as a collective accomplishment).

Educational research has indicated that collaboration can improve the quality of the learning process and learning outcomes. There is a broad range of types of supporting tools specifically aimed at helping students carry out learning tasks. Research has also shown that simply putting children into groups and leaving them to solve problems with a tool by themselves is not enough to ensure that they will use cooperation and dialogue to good effect. Tools need to be combined with appropriate pedagogy that prepares students for learning together and supports them while they do this.

For groups to be able to create a space of dialogue in an online learning environment and think together requires a learning process that focuses on more than just the task alone. Participating in group work and collaborative learning requires social skills that people also have to develop (De Laat 2006). Students are expected to learn constructively through dialogue with each other and collectively they are, to some extent, made responsible to take charge, control and manage the group's activity. Studies have shown that students need to be able to negotiate aspects of group work such as making plans, setting goals, discussing rules of engagement, responsibilities and expectations. Vonderwell (2003) found that network learners actively coordinated their learning by agreeing on rules, deadlines and responsibilities. Learners, according to Vonderwell (2003), needed to learn to adapt in order to gain learner autonomy as well as to learn strategies for effective collaboration. Hammond and Wiriyapinit (2004) also reported that the participants were actively scheduling their activities and assigning roles within the group as well as exploring the content and reflecting on the nature and purpose of group work. Therefore, besides developing a sense of community in which they get to know each other, build a climate of trust and promote group well-being, learners need to develop group-regulation skills to be successful as a learning community. When students are managing their group learning, they require awareness of each other's learning styles and strategies. L2L2 therefore involves a form of social metacognition that extends knowledge about oneself as a learner to include knowledge about all the members of the group as learners and how these members work together.

In summary, L2L2 is regarded as a complex competence that requires that all the group members are able to coordinate, regulate and plan the learning task by balancing issues of individual ability, motivation and expectations through constant dialogue.

Viewed through the analytic lens of the group or collective, in our study, through pedagogy and the visual language, we have promoted the students' development of the next four L2L2 skills (Yang et al. 2013):

Encouraging Distributed Leadership Moves Leadership is not just the job of the leader but it also requires the cooperative efforts of others (Hollander 1978). To view leadership as a reciprocal social process instead of the property of an individual, leadership responsibilities are shared within the group, and there may be no sharp boundary between leaders and followers (Li et al. 2007).

Distribution of leadership in groups has both social (e.g. Crow et al. 2002) and situational (e.g. Steed et al. 1999) aspects. In our work, each activity stage of the visual language represents a snapshot of the group learning situation, which reveals a need for different kinds of leadership distribution pattern. All students should be able to constantly negotiate the distribution of leadership according to situational and social change. This awareness of distributed leadership around particular topics breaks down dominating coalitions, hierarchical relationships, social exclusion and isolation.

Being Mutually Engaged Through/Around Shared Objects Mutual engagement ensures the coherence of a community over time and is therefore an essential component of any practice (Wenger 1998, pp. 737–735). Shared object/artefacts provide a rich repertoire of referential anchors for mutual engagement and understanding. Crook (1994) argues that there is a developmental line from children's secondary intersubjectivity and symbolic play to sophisticated reciprocal understanding and shared knowledge. In children's symbolic play, the material world plays a crucial role in the coordination of play activities and in creating a shared framework for collaboration. In our work, the shared model of the group learning process, which is made explicit using the visual language, plays a crucial role in supporting mutual engagement and creating a shared framework for collaboration.

Peer Feedback and Evaluation In our work, the first direction is the evaluation done between peers when they work together (c.f. peer assessment). Peer evaluation is done while students work together using the planning or discussion tool and by sending messages with the message tool. Students could use different tools to give peer feedback. For example, feedback related to L2L2 aspects and issues in the domain could be given through the message tool and feedback related to awareness for L2L2 could be given by using visualization of landmarks in the breaking news section, reflection tool and message tool. The second is constantly evaluating the way the group members work together. These two directions are supported directly by the Metafora suite of tools and are formative in that they provide learners with information that can help assess and improve their L2L2 process.

Group Reflection on the Social Dimension of Learning As a shared object, a representation of a group learning process constantly evolves and students' shared understanding of the object can be considered as a process of knowing. To make this process of knowing explicit to the group, we identified three distinctive orientations for group reflection, which can be conducted around an online discussion map:

1. Reflecting on individual preferences, collective responsibility and intended level of participation.
2. Reflecting on emerging roles, norms and gaps between individual and collective outcomes.
3. Reflecting on original group learning interpersonal structure and emergent structure, intended individual learning outcomes and achieved outcomes.

These three reflection points are proposed as possible opportunities for learners to think beyond their shared model of group learning process, and emphasize how different types of group regulation and coordination are needed in relation to evolving model.

4 The Web-Based Learning Environment: Metafora

Metafora aims to provide a holistic environment in which students will collaboratively plan and organise their work, as well as collaborate in solving science challenges over a relatively long time period. We present our platform (see Fig. 11.2), which serves both as a toolbox of various learning tools and as communication architecture to support cross-tool interoperability. The toolbox facet of the system provides a graphical container framework in which the diverse learning tools can be launched and used. Basic functionalities that are globally available are the next four: (a) the challenge, (b) the planning and reflection tool, (c) the discussion tool—

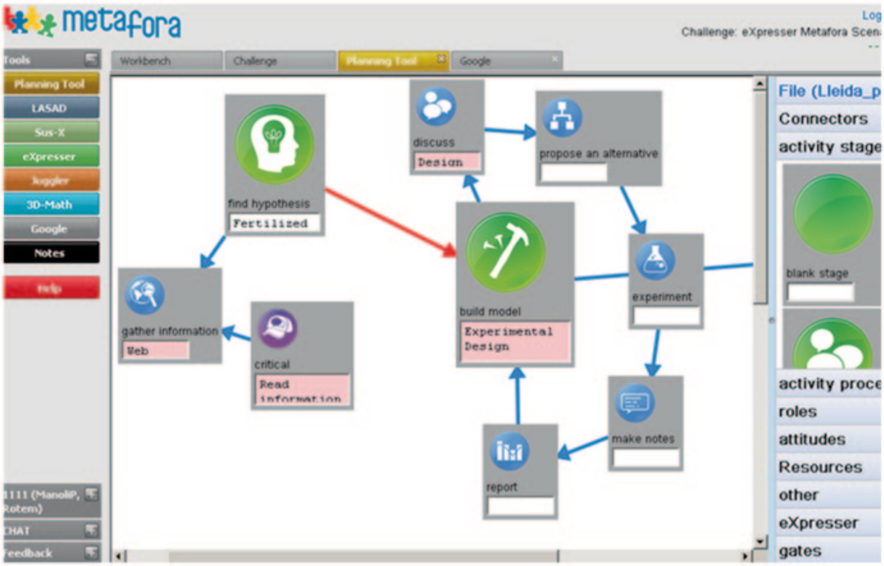


Fig. 11.2 Screenshot of the Metafora platform with several learning tools opened. The planning tool is shown in the centre

Learning to Argue: Generalized Support Across Domains (LASAD) and (d) the microworlds (Sus-X, eXpresser…).

In Fig. 11.2, it can be seen that these four functionalities are clickable for the students on the left-hand side of the screen.

Next, we describe briefly each of these four tools integrated in the Metafora platform:

The Challenge Challenge-based learning methodology was pioneered by the education staff at Apple Inc. and aims to engage learners in meaningful learning context, authentic connection with multiple disciplines, multiple points and multiple possible solutions and focus on the development of twenty-first-century skills (Johnson and Adams 2011).

The Metafora project incorporates challenge-based learning objectives. At the beginning of a typical Metafora-based activity, a group of students is formed and receives a relatively complex assignment—the challenge. The challenge is built in a way that will require the students to plan how they are going to approach the solution in order to reach it on time. After planning, the group begins with an iterative process entailing enactment—discussion—revision of the plan, until the team obtains a solution for the challenge.

The Planning and Reflection Tool The planning/reflection tool offers a visual language that enables students to create and map representations of their work for planning, enacting and reflecting on Metafora learning activities (see the centre of Fig. 11.2). The main feature of this tool is the use of cards and connectors to

Table 11.3 Components and explanation of the visual language

Component	Explanation	Visual example
Activity stage	Key stages of dialogic inquiry-based learning process, e.g. explore, reflect on process	
Activity process	Key activities to concretize the process of each activity stage, e.g. report, anticipate	
Attitude	Key intersubjective orientations to specify the group attitudes during activity stage and process, e.g. critical, ethical	
Role	Key roles to manage and mediate collaboration and cooperation between learners and groups, e.g. manager, evaluator	
Resource	Available resources for activity stages and processes, e.g. group discussion map, microworld artefact, etc.	
Connector	Key relationships between all the components, e.g. causal relationship, temporal relationship	

present a plan for future work or to create a diagram of work completed for reflection. The cards contain visual symbols and titles, as well as space to insert free text (see Fig. 11.2). The symbols and the titles represent different stages and processes related to inquiry learning (e.g. experimentation, hypotheses), attitudes taken towards the group work (e.g. being critical, being open) and cards that allow access to different resources within the Metafora tool box (e.g. the discussion tool called LASAD, microworlds). The connectors represent relational heuristics ("is next", "needed for" and "related to") to explicate how the various cards are related in the given plan. Therefore, the visual language included in the planning and reflection tool has six types of components and they are presented in Table 11.3.

Although it is built as a stand-alone web application, it is most effective as an embedded tool within the Metafora platform, acting as an entry gate and pivot to the other tools. Students can create and modify plans for facing various challenges in math or science. The students can also invoke other tools, including microworlds and discussion tools, and utilize them through specialized resource cards that are part of the visual language.

With the planning tool, students describe how they will tackle their current challenge using the visual language as a guide and then move together through the various planned stages, enacting activities and noting when activities are started and completed. Thus, the plan is also a visual representation of the groups' achievements and current status.

Discussion tools Metafora not only provides discussion tools to allow general communication and collaboration but also aims specifically to support the L2L2 process by allowing discussion and argumentation spaces to integrate artefacts created in other tools. Two discussion tools serve different purposes. First, the chat tool offers a quick and ever-present space for students to gain each other's attention and share informal thoughts in situ. Second, LASAD (Loll et al. 2009) offers a structured approach to discussion through argumentation graphs (see Fig. 11.3), which have been shown to improve discussion and argumentation skills (Scheuer et al. 2010). Both the chat functionality and the LASAD system are customized to display and offer links to referable objects that reside within other tools.

These referable objects are artefacts shared from other tools that not only can be viewed (text or thumbnail images) as components of the discussion but can also be accessed in the context of the original tool through return links. This need emerged from early experimentation with the system and was supported by previous related research (e.g. Stahl 2006).

Figure 11.3 shows a discussion in LASAD in which a referable object from the planning tool has been embedded—experimentation icon. In this LASAD discussion, students are arguing how they are going to design their experiment to test their hypothesis.

Microworlds Various microworlds (Kynigos 2007) which support constructionist learning in mathematical, scientific and socio-environmental domains are also integrated in the Metafora platform. Students, in order to solve specific math and science challenges, might use one of these microworlds.

The research study we present in this chapter has not used any microworld and focuses on the implementation and evaluation of the planning and reflection tool using a visual language representing the key components and features required for L2L2 and for shared scientific inquiry.

5 Objectives and Research Questions

In our research study, we had two main objectives:

1. To understand and specify Metafora's potential affordances to promote the learning and reflection about scientific enquire processes.
2. To study how Metafora's potential affordances may support students' development of L2L2 skills.

This study was conducted as a design-based research (Wang and Hannafin 2005) in which our research questions were the next three:

- RQ1: How does the visual language help students to solve the challenge using key scientific processes?
- RQ2: How does the visual language stimulate discussion and reflection about scientific processes?
- RQ3: Does the visual language help students to develop collaborative learning processes?

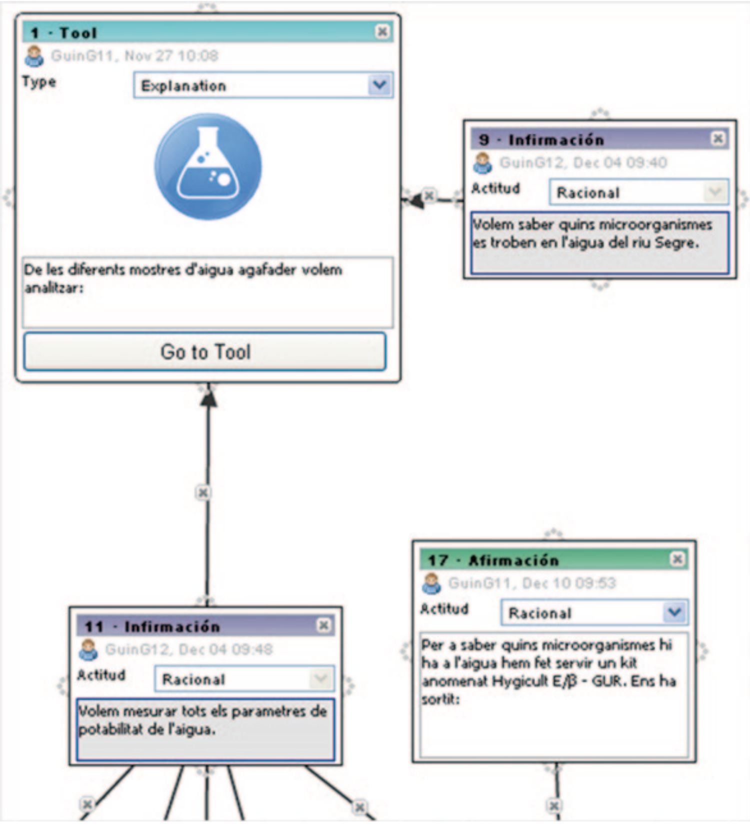


Fig. 11.3 A discussion map in LASAD with embedded referable object—experimentation icon—from the planning tool

6 Method

6.1 Participants

Eleven secondary students of year 11 (16 years old) participated in our study. Students worked in three groups to solve a challenge-based science project. Students worked on the challenge during nine class sessions.

6.2 Procedure

The teacher began introducing the challenge and the visual language to the students. She used the interactive blackboard.

The challenge was:

> The water and environmental European committee has fixed in its normative 2000/60/CE that all European rivers have to be in good ecological conditions in 2015.
> A study of this European committee realized in 2008 found that Segre River (Lleida, Spain) was in good ecological condition only in 75 % of its course. The most polluted section of the river is when the river crossed the town of Lleida.
> What scientific and rigorous proposals could you think about to influence on the society on solving the rivers' problem. Your ideas and actions might be at different levels: authorities, media, society and peers-secondary schools. Write or design a strategy to present your results to the society.

Students were provided with some net resources about: (a) main causes that may pollute the river, (b) ecological good health levels of river and forest and (c) water parameters. These resources were selected by the science teacher. Besides, students could check the Internet.

Afterwards, students planned and solved the challenge using the Metafora planning and reflection tool. The pedagogy used during these sessions was:

- Students worked in small groups during all sessions.
- Work-in-progress presentations and group debate sessions were carried out. Three times during the workshop, every group presented their working progress. In this presentation, students were asked to present not only the work done so far but also the group thinking process: reflect and present their discussions, problems, how they overcame them, use of visual language, collaboration, etc.
- Final group work presentation and whole class discussion were conducted. Every group presented the whole work and the group proposal to influence the society on solving the rivers' problem.

6.3 Data Collection

- The students' group work realized on the computer and students' group discussion during small group work were video–audio recording using a video recorder programme—CAMSTUDIO
- Video-recording sessions of work-in-progress presentation and final presentation
- Video recording of students' dialogue while working together

7 Findings

7.1 How Does the Visual Language Help Students to Solve the Challenge Using Key Scientific Processes?

To answer this research question, we analysed the small group work in the planning tool and their work-in-progress presentations to the whole group class—in which students present what they did, for which purposes, what scientific processes they planned in order to better solve the challenge and the small group worked. All the groups organised their challenge resolution process around the "activity stage" icons which represented a scientific objective to solve the challenge.

Analysing the planning and the icons used by the three groups of students, we observed students took into consideration the next five scientific inquiry stages:

- Define the problem.
- Hypothesis.
- Hypothesis evaluation (methodology—experimental design).
- Discuss findings.
- Draw conclusions and proposals to solve the challenge.

These findings show that the Metafora planning and reflection tool supported students' creation of an inquiry process because students establish the main scientific inquiry stages highlighted in the literature (e.g. Hakkarainen 2010; Shimoda et al. 2002).

Besides, students used the visual cards related to "activity processes" to unpack the processes and actions of the scientific activity stages. The use of the "activity processes" helped students to better define and fulfil the scientific objectives of each activity stages. An example of how students unpack the processes to better define their hypothesis is shown in Fig. 11.4. In this example, students decided to gather new information and evaluated it critically in order to confirm or not their hypothesis.

Furthermore, the analyses of the data showed that "activity processes" icons were mainly used for the next three purposes:

1. Activity processes icons were used as an aid to start thinking in possible actions: brainstorming. An example of this purpose is presented next:
2. Activity processes icons were used as a help to reflect about what they did and consequently plan the next step to solve the challenge. An example of this purpose is presented below:

> Ok, let's see, previous knowledge, and then we observed the data, explored the cartography link and the water agency link, and then we researched for new information.
> …But we don't have enough I think now we have to obtain new data about the river: look at this map [[open a link from the web resources]] it's clickable! It shows the quantity of water of the river at different points. How much water does it have in the different stages of the river? and in Lleida? Look We can compare them.

3. Activity processes icons were used as an aid to organise and structure their actions. Next, we present an excerpt in which can be seen how students discuss about how to reorganise in the planning tool the actions they have already done and from that how students rethink their planning:

Ada: I would put all of this in one block: reflect and analyse. All the information we have in here …Thus, all this information [[pointing at text written in one of the boxes]] is the information we got reading on the web.

Aln: Yes

Ada: I will put the icons reflect and analyse, because we have already analysed it, haven't we?

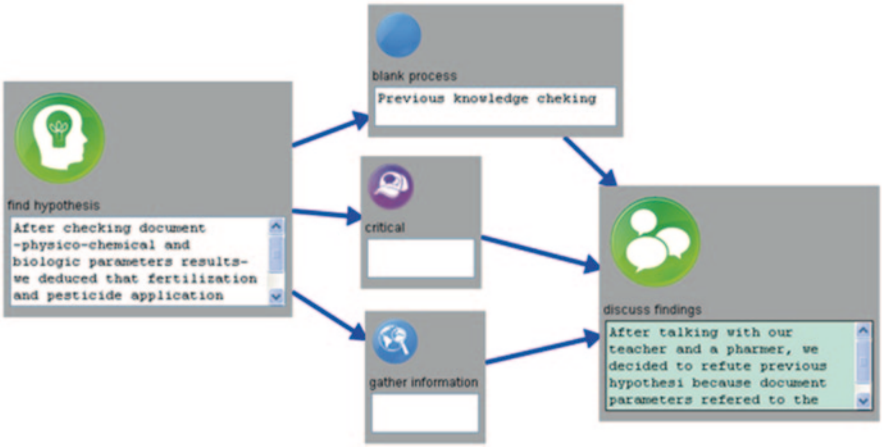


Fig. 11.4 Example of how students unpack the processes to better define the hypothesis

Aln: wait, wait, say it again and I will put the icons
Ada: I try to say what we are doing now?
Aln: Yes, and I agree [[she looks for an icon and drug to the computer screen]]
Ada: Brain storming [[this is the icon that Aln druged]] no, no, this later. We have done is analyses…

The observation of the planning process combined with feedback from students' in-progress presentations suggests that "activity stages" and "activity processes" visual icons promoted students to consider aspects of the scientific research process that they would not have thought otherwise. Therefore, the visual language included in the planning tool enriches students' scientific enquire processes.

7.2 How Does the Visual Language Stimulate Discussion and Reflection About Scientific Processes?

We transcribed and analysed the dialogue of one group of students in one class session. First, we track in the transcription for words related with the visual language. In Fig. 11.5, we compare the number of times students used an icon in the planning tool and the number of times that the inquiry processes are embedded in students' dialogue. During this session, students intensively used the words of the visual language in their discussion. In this line, students used words related with the "activity stages" 30 times but they only put one icon of this category in their planning map. Students used in their discussion words such as: conceptualise the challenge, methodology, predict the results, hypothesis and steps to follow.

In relation to the impact of the visual language icons referred to as "activity processes": students included intensively during their group discussion words related

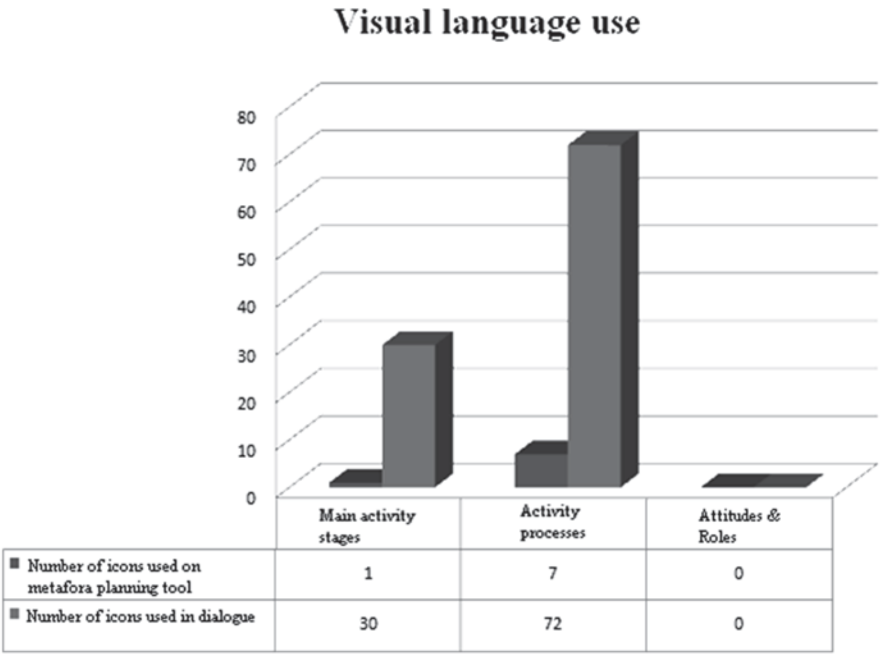


Fig. 11.5 Comparison of used visual language in the planning tool and in students' dialogue

to processes such as: analyse, observe, brainstorm, explore, search for new information, discuss.

From our point of view, this finding is relevant because it might confirm that the visual language had a positive impact on students' dialogue and on the way students organise their science thinking.

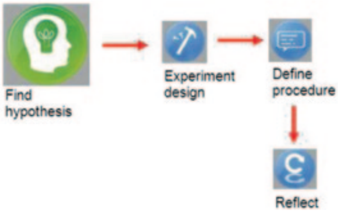
In future research studies, we intend to use "text analysis software" such as "Wordsmith tools" to better analyse the use and the impact of visual language on the learning of scientific inquiry processes.

Additionally, a deeper analysis of students' dialogue showed the presence of students' reflection about the most appropriate scientific processes to carry out in order to solve the science challenge. In Table 11.4, we reproduce an extract of this dialogue and it can be seen how Metafora visual language promoted and mediated the reflection about scientific process to solve the task.

7.3 Does the Visual Language Help Students to Develop Group Learning Processes?

In collaborative learning situations, the process of shared meaning making is seen as just as important as the actual outcome of the activity. In this respect, Mercer and Littleton (2007, p. 25) argue that collaboration involves "a co-ordinated joint com-

Table 11.4 Example of students' dialogue and students' actions in the Metafora planning tool

Actions in the planning tool—visual language used	Dialogue
	Ada: Let's see. When we do that then? Aln: So, in theory we are still here. We have not done anything, right? ((laughs)) Ada: Yeh…but from this, we should do an experimental design shouldn't we? Or something. Aln: If Ada: This is experimental design, right? [[looking for experimental design icon]] Aln: Wait, wait, wait. First are the hypothesis Ada: We need to define what steps we will follow first [[dragging the "define procedure" icon, and observe second DNLA: If…and reflect as well. Now we are reflecting, aren't we? Aln: If also Ada: thinking Aln: Here and to reflect put an arrow. So, after everything we've done we look in the mirror. Can I do it?… [[requested photocopies of the icons in the DNLA]] [[Ada recorded in the Metafora and put the last icons in the planning]]

mitment to a shared goal, reciprocity, mutuality and the continual (re)negotiation of meaning".

A key concept, related to this idea, is the concept of "intersubjectivity", which signifies the process of developing communality in joint activity. Linell (1998, p. 225) argues that, for collaborative projects to be successful and truly collaborative, all parties must be "mutually other-oriented". Additionally, in the context of computer-supported collaborative learning, Wegerif (2007) claimed that it is necessary to develop, through social interaction, a "dialogic space", which he sees as the social realm of the activity within which people can think and act collectively, thus opening up a space between people in which creative thought and reflection can occur.

In this section, we wondered if the Metafora planning and reflection tool stimulated and mediated the development of key L2L2 skills.

The analyses of the session we transcribed showed that students shared meaning making, took reciprocal perspective, were mutually engaged and created a dialogic space in which they thought and acted collectively. Next, we present an excerpt in which collaborative learning processes are explicit.

> Context: Students are analysing different graphics from a web resource about different levels of concentration of nitrites and phosphates in the water of the river in different periods of the year. Ada: tThat's strange…However, I still do not understand why during the watering season there is less [referring nitrites]. Maybe because they are more dissolved. I do not know.

DNLA: I suppose, because it is related with how many times you can water the fields, right?
Ada: Yeh
DNLA: You have to water the fields every 15 days, ok? When you do not have to water is because the humid is high.
Ada: Then, during the watering season, there is less water because the plants absorb it?
DNLA: Yes. Because the land absorb it. They have that.
Ada: Likewise. So the land, during the watering season absorbs water and in the water is where are the phosphates and nitrites, so is logical that there are less… and just when there is no watering… land does not absorb the water and then the water would pass without any difficulty and go to the river again.
Aln: Good explanation, different to my one… but yeh, what you have said is also possible.
DNLA: I know this because my uncle has a field, and I know that he waters every 15 days, and for 4–5 h, they put water in the field till the whole field is watered
Aln: Yeh… it can be, can be
Ada: Yeh, then we can base on this.
Aln: Ok
Ada: With what you are saying DNLA. It is true.
Aln: So if there is no watering, they are not fixed in the land [referring to fertilise] and they go to the river.
Ada: Yes

In this excerpt, Ada and Dnla are mutually engaged in developing arguments to explain what human actions may cause the different levels of nitrites in the water of the river depending on the month of the year. Doing so, Ada and Dnla build their arguments on each other's contributions; both students bring to the discussion different types of arguments and examples, and both students assess each other's arguments in order to build a shared explanation of the scientific phenomena.

Students showed an explicit effort to construct common and shared knowledge which would enable them to come to an agreed and common conclusion. In doing so, students assess and re-elaborate their own and other's ideas and reasons.

8 Conclusions

This chapter discusses the affordances of a new learning environment, supported by new technology that is currently under development: the Metafora system. L2L2 in science is a key complex skill or competence for knowledge age work. The Metafora project aims at developing a better understanding of this complex skill through specifying key features of learning together science processes that students need to be aware of and able to work with, and by embodying these features in a visual language which forms the main component of a planning and reflection tool.

We have reported a design-based research study in which the main objectives were to understand and specify the Metafora's potential affordances in promoting the learning and reflection about scientific inquiry processes and in supporting students' development of L2L2 skills.

Findings suggest that the visual language we have developed can help raise students' awareness of key collaborative scientific inquiry processes. The Metafora visual language helped students to unpack and reflect about the scientific processes to solve a complex science challenge. Additionally, the Metafora visual language promoted students' awareness about aspects and components of their collaborative learning processes in science.

The development of this visual language and its initial successful trials have potential pedagogical significance in science education. In our study, the tool has shown itself to be of value to science teachers who need to teach not only the content of science but also the process of scientific inquiry. Students of our study reported that Metafora helped them to reflect about the nature of scientific methodology and about scientific inquiry processes followed by the group. The Metafora planning tool allows the representation of a shared inquiry process. This representation helped students to better understand the scientific methodology and how to apply it in a specific context.

However, further research is needed to investigate the impact of using this tool on the ability of students to learn together with others in new situations. Our design-based research has explored how the combination of pedagogy promoting talk and collaborative dispositions in students worked together with the visual language tools to stimulate L2L2. Future research could use this evidence to produce a further design framework for an improved implementation of the Metafora system, working closely with teachers to improve the pedagogy to increase the quality and quantity of L2L2. Further research is already planned to explore the potential of the Metafora planning and reflection tool to support distributed individuals learning together via the web.

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