Towards Supporting 'Learning To Learn Together' in the Metafora platform

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Abstract. Computer-Supported Collaborative Learning (CSCL) has been demonstrated to improve student interaction in complex collaborative learning scenarios. When orchestrated appropriately, it also provides opportunities for learning high-level social learning skills, or "learning to learn together" (L2L2), but these opportunities are often only dealt with implicitly. This paper presents work towards an intelligent system that can scaffold L2L2 across many domains by (a) offering carefully-designed message templates that encourage peers to communicate with their groups about their learning process, (b) analyzing student work and recommending a specific set of these message templates that are pertinent to their moment-by-moment interaction. We present methods by which the system can use automated analysis techniques to recognize opportunities where students might benefit from these messages, and either send the message directly or prioritize message templates for students' use.

Keywords. Computer-Supported Collaborative Learning, Exploratory Learning Environments, Learning to Learn Together, Intelligent Support of Social Interaction

1 Introduction

The Computer-Supported Collaborative Learning (CSCL) field has demonstrated that success in complex collaborative environments depends on several factors including the type of task, the learning scenario, and the collaborative skills of the students involved. When orchestrated appropriately, these types of learning scenarios provide opportunities both for domain related learning and social meta-learning, or 'learning to learn together' (L2L2). However, for this to be possible, students and teachers alike need tools to elevate their conversation beyond solely subject matter, to recognize and practice high-level collaborative learning skills (L2L2 skills) in tandem with domain skills. Beyond simply providing appropriate interaction spaces, one of

the goals behind CSCL and AI in Education systems is to provide more structured guidance. This type of automated support, however, is challenging in these complex scenarios, due to the variance in domains, learning scenarios, and intricacies of interrupting collaborative learning processes at appropriate points in time. All of these considerations limit the applicability of standard techniques for providing direct feedback.

With these challenges in mind, we argue for a broader perspective on the role of both feedback and AI in such scenarios. As discussed in [1], feedback in collaborative settings can manifest in many different ways, rather than limiting intervention mechanisms to messages flowing directly from an AI analysis system to individuals. We suggest a design where students, teachers (or facilitators in general), and automated agents can all offer feedback to individuals and groups, with the support of the system. Thus, the system takes on an additional role of providing tools and scaffolding to help students offer feedback to each other (a more indirect presentation of feedback). This scaffolding can be provided through *message templates*, generic phrases that focus attention on L2L2 concepts and can be tailored to fit the specific scenario at the time of use. These message templates are available in an intuitive and easy-to-use tool that enables students to send messages to one another, or for teachers to send messages to students. Utilizing this functionality, the AI system can go beyond the traditional role (i.e., direct presentation of feedback messages), to also scaffold the users in sending messages to each other (indirect presentation). To accomplish this, the AI system can recommend the most relevant message templates at any given point in time. Key questions to address when taking this approach include:

- What kinds of messages are most likely to promote L2L2 within task-focused group work?
- How can an intelligent system be developed to understand and identify when these messages might be most effective?
- How should the system deliver these messages or encourage the users to deliver them?

The rest of the paper is organized as follows. We first describe the context where this work is situated, in particular the Metafora platform and pedagogy that is being developed in the EU-funded Metafora project [2]. In Section 2, we briefly present the system and the key components of L2L2 that it is designed to help students develop and practice. In Section 3, we describe our process for developing appropriate, generally-applicable messages, and how these so-called 'message templates' are made generic and available for use within the system through techniques that allow the system to recognize and automatically respond to L2L2 behaviors. To conclude, we discuss our initial findings and future plans with respect to evaluating the approach.

2 Background and relevant work

2.1 The Metafora system and project

To support the L2L2 process, the Metafora project designed a platform that includes a planning tool designed for explicating and reflecting on the group learning process. Additionally, the platform contains the LASAD discussion environment [3] for developing arguments or discussions around the topics that emerge during the collaborative process. Of course, teaching these higher-level learning skills cannot be done without grounding the work with genuinely challenging tasks that require critical thinking skills (c.f. [4],[5]). The Metafora system offers a broad range of such learning activities across math and science by providing a suite of exploratory learning environments (microworlds and simulations). All of these tools are brought together in the Metafora platform, which serves both as a toolbox and as a communication architecture to support cross-tool interoperability. As a toolbox the system provides a graphical container in which the diverse learning tools can be launched and used (the Figures in Table A.1 give an impression of the Metafora system with the platform parts on the top and left borders and the graphically integrated tools in the main panel from center to right).

2.2 L2L2 in Metafora

The Metafora platform and tools have been designed and implemented to provide support for key components of L2L2, defined through both literature review and design-based research. In the interest of space we refer the reader to ([2]; [6]) and the project deliverables (see http://www.metafora-project.org) but in brief the four L2L2 aspects are as follows:

- *Distributed leadership:* each of the group members assumes leadership, encouraging both individuals and the group to make progress towards goals on both intellectual and managerial levels.
- *Mutual engagement:* group members co-construct, discuss/argue, or seek/offer help about mutually shared artifacts.
- *Peer Assessment and Feedback:* group members constructively evaluate *the results* of work done by themselves, their peers, and their group as a whole.
- *Group Reflection:* group members consider *the process* by which they will accomplish, are accomplishing, or have accomplished their tasks.

We see in our current research efforts [2] and ongoing experimentation that this system offers an environment in which L2L2 skills can be practiced in many scenarios. However, we recognize that presenting the learning environment without further support may not promote L2L2 explicitly, especially for novice learners, as other literature also suggests (e.g. [7],[8]). The challenge of promoting L2L2 explicitly necessi-

tates identification of the key elements of social interaction. In this way, support and reflection can target these key elements to make collaborative learning effective.

3 Promoting L2L2 through sending and recommending messages

As described earlier, our approach to L2L2 intervention and support is to provide a tool that guides and enables students to effectively interact with one another. Other research has demonstrated the potential benefits of supporting peer tutoring, (e.g. [9],[1]). Others are also taking the approach of using an AI system to recommend feedback that should be given by a human mentor [10]. We attempt to apply both of these principles to work within our L2L2 framework, where we encourage students to engage with peers by spontaneously taking on the role of mentor, providing timely feedback and initiate discussions about their learning process To enable and encourage students to engage in these activities, we developed a messaging tool that promotes students in using specific messages to engage in L2L2 and regulate their own collaboration. This tool provides students with the means to be their own facilitators, interacting with their peers or entire group as necessary. In addition, this same system provides a method for teachers and automated agents to offer similar interventions. In order to scaffold L2L2, the system offers specific speech acts, implemented as message templates, to focus students on the high-level concepts of L2L2. Creating well-targeted, supportive, and helpful message templates is crucial to the success of such an approach, and therefore we took an iterative, data-driven approach to understanding what specific speech acts might promote positive L2L2 behaviors. These speech acts, which were collected from actual student and teacher dialog, were then abstracted as message templates, applicable across the wide range of Metafora scenarios.

3.1 Sending and receiving messages

The Messaging Tool was developed to satisfy requirements that both our previous research with similar tools [11] and early pilots allowed us to identify. While providing some scaffolding for the previously mentioned reasons, the tool also had to be simple and speed up (rather than delay) interaction between students. In addition, we wanted to provide not only opportunities for reflection but also flexibility to students and the ability to adapt the messages to their specific situation and task. As such, the tool is equipped with what we refer to as *message templates,* sentences that correspond to the four L2L2 aspects and refer in a general manner both to the stages of the students' current activity, and the different tools they may be using (particularly the planning and the discussion tool).

Any group member can select one of these message templates and then potentially edit the template to adapt to the particular situation. The messages that are sent with the tool are kept for further reflection (Fig. 1, the "sent" tab). A snapshot of the

tool appears below. Fig. 1 shows the tool from which messages are sent, and Fig. 2 demonstrates how the message appears for students receiving the message.

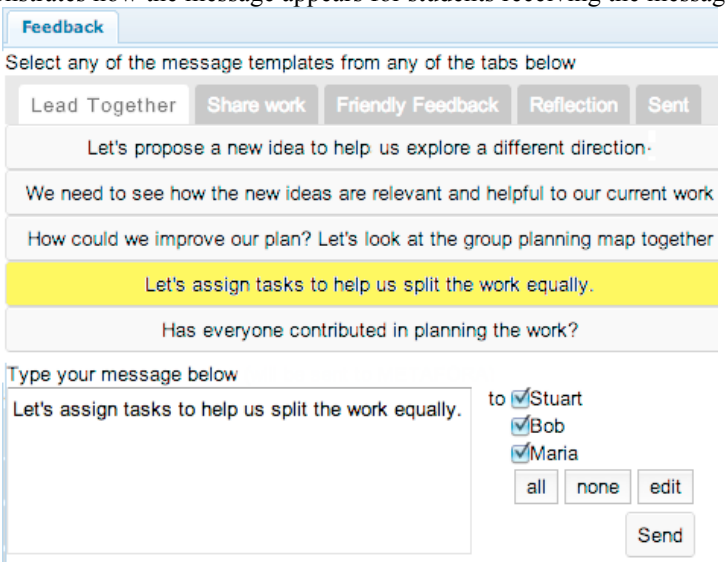

Fig. 1. The **Messaging Tool**. Students can choose and edit messages templates from each tab representing the different L2L2 aspects (the titles are adapted to children-friendly version)

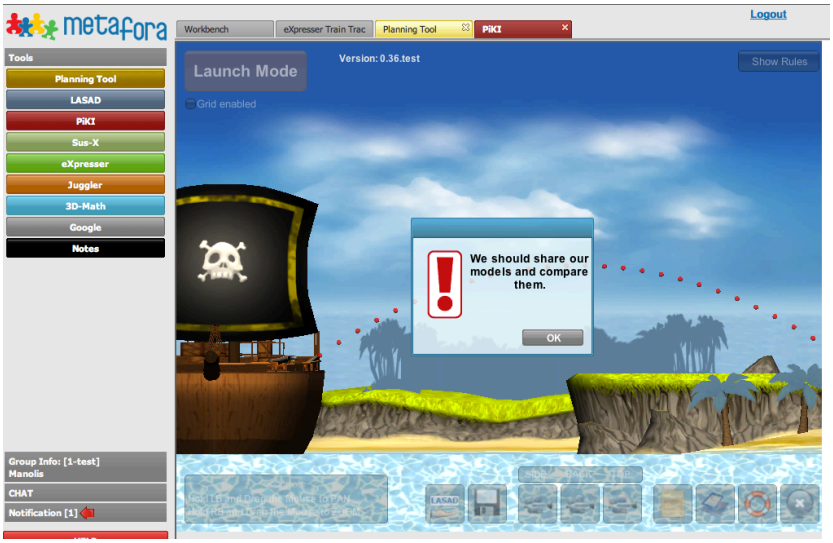

Fig. 2. Once a message is sent, it appears as pop-up anywhere that the students are working. In this case, a student is investigating their PIKI construction without much attention to the work of the rest of the group, and another student requests that they share and compare their work.

The system includes two types of message templates — peer and external — both created based on previous studies and Wizard-of-Oz experiments (c.f. [12]). Peer message templates are designed to address the group of students working together, and are sent by individual students to the rest of this group. These messages are designed to scaffold group work. External messages are equivalent messages that the system can send (whenever appropriate) as interventions. This list of 'external' messages can also be used by a teacher or any facilitators, who can launch the system separately and use it to support the students, as described in [12] where we presented similar work using these tools to simulate the provision of messages). Table A.2 in the appendix presents a tentative sample list of message templates.

3.2 Delivering and Recommending Messages

In early experimentation we observed a potential limitation of the messaging tool, in that it was challenging to identify quickly the most relevant L2L2 aspect and message templates. Taking into account that reflection is better encouraged when in context, we designed the system for highlighting (recommending) pertinent messages based on students' recent work.

This recommendation relies on a cross-tool analysis component that gathers historical data and can analyze pieces of evidence which we refer to as *indicators* (a statement of user activity from any tool in Metafora) or *landmarks* (a high-level statement of some abstract concept occurring in Metafora, indicative of accomplishment or need for remediation) that are generated by the different tools (for early steps in this approach see [13]).

Our challenge was to identify high-level student behaviors that call for intervention. From the superset of all L2L2 behaviors identified through data analysis, we select behaviors that are high-level enough to be directly relevant to L2L2 through conceptual links with the L2L2 definition, but also low-level enough to be directly mapped to certain actions within the system. Obviously, generality is a challenge, as each tool reports indicators and landmarks that are meaningful to the use of the specific tool, but not necessarily to the use of tools more generally. Therefore, we also require landmarks that can be understood in a generic sense across all tools, landmarks about which the cross-tool analysis component can reason. We have defined three broad labels for landmarks coming from the different tools that allow for cross-tool recognition and decision-making:

- *Perceived Solution*: an evaluation of an artifact produced within a tool that the students may consider a solution (but is not necessarily a solution).
- *Possible Solution*: a positive evaluation of the student's work that (based on some heuristics or criteria) is considered an acceptable solution to the given task.

- *Apparent Struggle*: some negative observation of a production process, outcome, or interaction that indicates intervention is necessary.

The cross-tool analysis component can then use these labeled landmarks and, in combination with the low-level action indicators, look for patterns across students that are indicative of L2L2 and provide opportunity for potentially fruitful intervention.

There are two distinct interventions that the automated support can send. First, a *direct message* exploits the system's interface for messages to directly present an L2L2 message (selected from the templates) to the student(s). This is a traditional form of AIED feedback, where students receive some targeted advice about their work from an automated system. This type of intervention has the advantage of directly requiring the students' attention, which can ensure students are receiving the necessary feedback. However, the direct approach has the disadvantages of being forceful and of taking control away from students.

In contrast, the second intervention method comes in the form of a *recommended message template*, a type of intervention where certain message templates in the messaging tool are highlighted in order to make clear which messages are most pertinent to the student's current situation.

We hypothesize that this recommendation intervention has multiple benefits. It has the potential to increase the students' involvement in the meta-level regulation of their own learning process, because the recommendations only hint to a student what might be most relevant, but still leave the onus on the student to engage in the L2L2 process. Additionally, a practical advantage to the recommendations is that if the AI system misjudges a situation, this will generally cause less harm. Table 1 contains examples of interventions as an outcome of analysis information shared by the tools for particular behaviors.

Table 1. Examples of mapping L2L2 behaviors to a specific pattern of indicators and landmarks that can be recognized by the cross-tool analysis component, which in turn can enact the given intervention. Examples of behaviors are related to the examples from section 2.2.

	Behavior	Indicators and Landmarks	Intervention
Distributed Leadership	Different members of the group should take the initiative to introduce and discuss new ideas.	- One person in the group creates a new resource. - Lack of discussion (in LASAD or chat).	*Recommended Message:* "This is a new idea. We should discuss how it is relevant and how it can help us."
utual En-gage	Group should work together	- Divergence without convergence in plan-	*Recommended Message:* "Lets discuss why we have

	in a supportive and integrated way.	ning /reflection tool (Apparent struggle). - Lack of discussion (in LASAD or chat).	disagreed in LASAD, explaining first what is tricky about the task and what we are not so sure about."
Peer feedback and assessment	Group members should consider solutions offered by others and how those solutions relate to their own solutions.	-Apparent solutions from team members on separate computers -Apparent solutions not shared in LASAD, not accessed by other members	*Recommended Message:* "Lets evaluate one another's solution with respect to our task" *Direct Message:* "You should consider your solutions with respect to the task."
Group reflection	Group should re-visit and reflect upon their plan as they work	-Lack of plan revision with abundance of indicators from other tools. -Lack of attitude or Role cards	*Recommended Message:* "Let's revise the plan to show how we are going to work as a team." *Direct Message:* "You should consider how attitudes have played into your planning."

It is important to note the varied use of recommended messages vs. direct messages in the intervention column of Table 1. While each specific decision to send a direct message vs. recommendation can be debated from an instructional perspective, it is clear that certain situations may call for direct intervention because the situation is deemed as critical and the system has high confidence in its diagnosis. The difference between direct messages and recommended messages can also potentially be used as scaffolding, and faded over time. More direct messages early on can help students learn how and when these messages might be appropriate, and over time they can then be given only as recommendations, when students are expected to offer messages to one another in productive ways on their own.

Lastly, while this research is not focused on the teacher, this messaging system invites teacher participation as well, allowing them to send messages to student groups. Similarly, teachers can receive the recommendations from the system to help them quickly and easily identify the types of messages that are most likely necessary for any given group at a particular point in time. In this way, a single intervention system based on messages is acting as: 1) an intermediary for students to interact with each other, 2) a tool for teachers to interact with the students, and 3) a system for automated agents to offer intervention on varying levels of interruption.

4 Conclusion

This article presents an attempt to support social regulation in a collaborative environment known as Metafora with an explicit aim to support Learning to Learn Together (L2L2). The system, through both its design and automated support system, helps students become aware of many requirements of effectively learning with others in a group by explicitly referencing and drawing attention to the four L2L2 aspects. Since the Metafora platform and pedagogy are aimed at not only teaching domain knowledge — where approaches in AIED and ITS have demonstrated their potential — but also attempting to help students reflect on L2L2 by encouraging them to plan and regulate their own learning, we recognize that developing a 'traditional' intelligent system that sends feedback directly to students is not necessarily an adequate solution. Apart form the typical challenge of deciding when and how to provide feedback, there are conceptual challenges to ensuring this feedback encourages high-level reflection on L2L2 and that the feedback is generically available and applicable for all domains and learning scenarios.

This paper offers a new conceptualization of what an AI intervention (in the general sense) can look like: a system where fundamentally equivalent, theoretically grounded message templates can be utilized by different stakeholders (human or AI agent) according to the needs, abilities, and circumstances of the given scenario. Apart from making these message templates available for students to consider and exchange, the same basic messages can either be catered to be sent directly to students (with appropriate justification) or be recommended to students or teachers as potentially pertinent to the situation. Pilot experimentation suggests that these recommendations act not only as a practical means of helping students select from a large list of potential messages but also as a scaffold in suitable moments, to help students develop "L2L2" ways of thinking that can support them in becoming better group learners.

In future work, we intend to investigate in more detail the potential of both the availability of those messages in comparison with a less scaffold approach, and particularly the added value of the recommended messages vs. simply encouraging students to use the messaging system in general. Our hypothesis is that the sheer availability of the messages stimulates reflection and has the potential to improve awareness on L2L2. However, our previous work and initial pilots suggest that when messages are recommended based on relevance to the context, we will see even more significant behavioral changes in groups due to these messages, especially when students have ownership of the messages.

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Appendix

Table A.1. Tools used in all learning scenarios

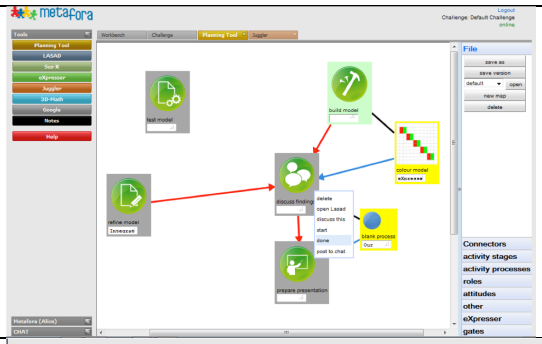
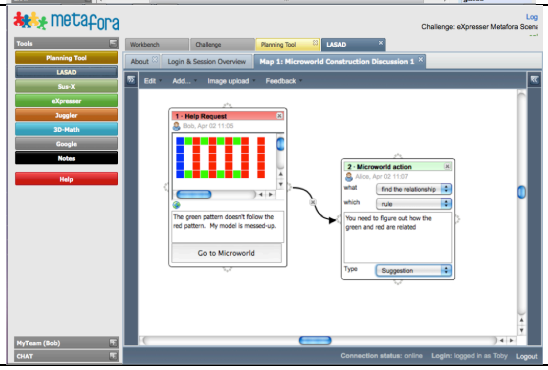
Planning/Reflection Tool: provides a visual language to support students in planning and reflecting; activities, roles, resources, task assignments, and attitudes are visualized, discussed, and reflected upon.	
Discussion Tools: provide a shared workspace for students to have in-the-moment chat, as well as structured discussions and argumentation, through a graphical argumentation tool, LASAD (see more info https://cscwlab.in.tu-clausthal.de/lasad/)	

Table A.2. Examples of message templates to be sent by students or to be recommended by the system. Note that each message also has an equivalent message with adapted language and grammar that appear as external to the group and can be used from the system as a direct message. For example, instead of "Let's look…" "Everyone should look…"

	Message Template	Comments
Distributed Leadership	Let's propose a new idea to help us explore a different direction.	Useful in a phase of brainstorming as a means of getting the team out of an impasse.
	We need to see how the new ideas are relevant and helpful to our current work.	Highlights the importance of regulatory moves during idea generation and provides an example of criteria for accepting or rejecting ideas.
	Let's look at the group planning map together.	Relevant when some students' activities seem to be diverting from the plan.
	How could we improve our plan?	Inspires specific leadership moves from members of the team. These messages promote the equal share of both work and leadership
	Let's assign tasks to	

	help us split the work equally.	(planning) from all the members of the team.
	Has everyone contributed to planning the work?	
Mutual Engagement	Has everyone done the work they said they would do?	Similar to the last two messages of the previous category, but intended to refer to engaging particularly with the discussion or work in the microworlds.
	Has everyone contributed to the discussion?	
	I/We need some help with <…>	Promotes peer help-seeking --- students are often reluctant to ask for help from peers even when stuck.
	We seem to disagree. Have we all understood each other's opinions?	Helps students step back from the "heat of the disagreement" and fosters shared understanding and by encouraging students to rethink the problem and help reach consensus and/or generate new action.
	Lets discuss our conflict starting from the causes of our confusion.	
	We seem to disagree. Lets redefine our group goals/attitudes/roles.	Defining goals/attitudes or roles involves students in a discussion about their different perspectives.
Peer feedback and assessment	We should share our models and compare them.	Sharing and comparing models promotes meaning-making with respect to the domain.
	Lets evaluate one another's solution with respect to the task.	Constructive peer assessment is an important skill but students often ignore the original task and tend to focus only on procedural rather than conceptual aspects hence this message recommends specific criteria.
	Let's explain clearly in our evaluation what is the problem	
	Let's revise our plan. Does it match our work so far?	Revising the plan at specific phases during and at the end of the collaborative process initiates reflective discussions.
	Let's use the attitude/role cards to reflect on our work so far.	Employing attitudes and roles in the plan encourages reflection on the collaborative process at the meta-level.
	Lets consider our best/worse moment as team so far.	A message often used in critical incident analysis as a way of reflecting and generating meaning out of events.