Towards the Development of an Adaptive Communication Tool Promoting Cognitive and Communication Skills

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Abstract. The work presented in this paper discusses the results of an initial qualitative experimental study towards the development of a communication tool with adaptive capabilities, which aims to facilitate group interaction, support the accomplishment of collaborative learning activities of different subject matters and promote the cultivation of cognitive and communication skills. The main objective of the experimental study was to observe how the process of the discussion, between pairs of students collaborating on the accomplishment of a learning activity, proceeds and to analyse their dialogue with respect to the cognitive skills that should be cultivated. In the framework of the study, we developed learning activities, addressing specific and similar cognitive skills, for three subject matters with different orientation. The students, who participated in the study, collaborated in an unstructured dialogue form using a computer-supported collaborative environment. Their dialogue was recorded in log files and was qualitatively analysed. The analysis revealed that the group dialogue presented similarities, as far as the structure and the use of specific phrases are concerned, in cases of collaborative learning activities addressing similar cognitive skills independently of the subject matter under consideration. Also, the analysis drew implications regarding the adaptivity of the communication tool on the basis of the cognitive skills that should be cultivated within the framework of each learning activity. The adaptive capabilities concern (i) the form of the dialogue supported (e.g. structured or unstructured, semi-structured or fully structured messages), and (ii) the "communication-scaffolding" tools (e.g. sentence openers, communication acts) provided, in order to support, facilitate and interpret the group dialogue.

Keywords: collaboration, adaptivity, cognitive skills, communication skills, sentence openers, communication acts

1 Introduction

The main advantages of collaborative settings for learning arise from the processes of externalisation, articulation, argumentation, conflict and co-construction of ideas (Barros & Verdejo, 2000; Dimitracopoulou & Petrou, 2003). During collaboration, the group members have to make their ideas explicit, prompt for justifications and negotiations, elaborate and reflect upon their knowledge and encourage participation, in order to converge to a shared understanding (Barros & Verdejo, 2000; Soller, 2001). Effective collaboration presupposes active and well-functioning groups that have the required skills to communicate and the cognitive skills to learn (Soller, 2001). Unfortunately, the students do not always possess such skills. Usually, the instructors help them to develop such skills and to cope with the requirements of effective collaborative learning.

In the context of Computer-Supported Collaborative Learning Environments (CSCL), the students need support and guidance in order to cultivate basic skills in communication and to collaborate effectively. A lot of research effort is devoted to the analysis of the dialogue between the group members and to the

development of appropriate "communication-scaffolding" tools, which guide the students during their communication. In most cases, the guidance takes the form of fully or semi-structured dialogue implemented through interfaces, which enable the students to select a sentence opener and/or a communication act from an available list (Soller, 2001) and initiate their contribution and denote, in this way, their intention/action. The underlying idea of the composition of such lists is the communication skills, which are most often exhibited during collaborative learning.

The work, presented in this paper, takes previous work in defining and structuring the group communication one step further by seeking to determine those cognitive and communication skills, and subsequently those "communication-scaffolding" tools, that can promote effective collaboration with respect to the cognitive skills that the collaborative learning activities are aiming to develop/cultivate to the students. More specifically, this work aims to contribute to the development of a communication tool with adaptive capabilities, which can improve, facilitate and support group communication during the accomplishment of collaborative learning activities of different subject matters addressing various learning outcomes. The communication tool constitutes one of the main modules of a web-based synchronous collaborative learning environment called SCALE: Supporting Collaboration and Adaptation in a Learning Environment, which is in the initial phase of development (Gogoulou et al., 2003). SCALE aims to enable the students to work on collaborative learning activities concerning various subject matters with different orientation, to guide the students at the communication and at the learning level through intelligent agents, to support alternative models of collaboration between the group members, and to provide adaptive capabilities as far as the communication tool is concerned according to the learning outcomes addressed by the learning activity and/or the model of collaboration.

In this context, we carried out an initial experimental study focusing on the investigation and the qualitative analysis of the group dialogue with respect to the cognitive skills that should be cultivated within the framework of the collaborative learning activities. The experimental results drew implications about the adaptivity of the communication tool regarding the form of the dialogue supported (e.g. structured or unstructured, semi-structured or fully structured messages), and the provided "communication-scaffolding" tools (e.g. sentence openers, communication acts).

The rest of the paper is structured as follows. In Section 2, we discuss related work in supporting/facilitating the group communication. In Section 3, we describe in detail the experimental study in terms of the process followed, the collaborative learning activities developed, the results of the qualitative analysis of the group dialogue and the initial conclusions that we drew. The paper ends with the main points of our work and our near future plans.

2 Background Issues

In computer-based collaborative learning environments, the group members should be able to exchange their ideas, to externalise their thoughts, to argumentate on their actions or on their points of view, to articulate their reasoning, to negotiate on their ideas, by sending and receiving, usually, written messages. The form of the dialogue may be totally free or fully/semi – structured, guided and supported by the appropriate "communication-scaffolding" tools such as sentence openers and communication acts. Existing collaborative learning environments implement group dialogue either (i) in a totally free form, or (ii) in a semi-structured form using sentence-opener interfaces comprised of organized sets of phrases (i.e. the students send messages to each other by selecting a sentence opener like "I propose to …", "I agree with …" from a menu and then elaborating on this opener with additional text) and/or communication acts (i.e. the students send messages to each other by selecting a communication act like "Request", "Propose" from a menu that corresponds to the students' intention/action and then expressing their intention/action with additional text). The semi-structured form aims to guide the sequence and the content of the dialogue and support the students in the development/cultivation of specific communication skills.

For example, in Belvedere system (Suthers & Jones, 1997), a "chat" facility software is included for unstructured discussions between the students, while in C-CHENE (Baker & Lund, 1997), the group dialogue is implemented in a semi-structured form using specific sentence-openers like "I propose to…", "Look at the experiment", "Wait!", etc. In DEGREE (Barros & Verdejo, 2000), the students have to select the type of their contribution (i.e. the communication act) (e.g. proposal, question or comment) from a list, each time they add to the discussion. In COMET (Soller, 2001; Soller, Wiebe & Lesgold, 2002), the sentence openers are grouped by the communication acts types in a structured interface. The definition of the sentence openers/communication acts is based on the analysis of the students' actions and their

conversation taking place during face-to-face collaboration or computer-supported collaboration. Research work has resulted into various taxonomies of conversation/communication skills that characterise effective group collaboration and facilitate recognition of active learning conversation (Johnson & Johnson, 1994; Robertson et al., 1998; Soller, 2001).

The free-form dialogue seems to be more appropriate in cases that it is needed to allocate tasks to the group members or to have discussions/brainstorming during problem solving, while the structured form can promote reflection, improve shared understanding and collaborative argumentation, increase task-oriented behaviour/decrease off-task behaviour and support the cultivation of specific skills (Dimitracopoulou & Petrou, 2003). Also, the structured form of the dialogue enables the automatic interpretation of the students' interaction without having to rely on natural languages parsers and facilitates the development of effective monitoring and intervention mechanisms.

Considering sentence openers in relation to communication acts, sentence-openers may force the students to "fit" their contribution to one of the available sentence openers trying to select the most appropriate one and risking to change the intention of their contribution (Soller, 2001) in case they misunderstand the meaning of the sentence openers or in case the desired sentence opener is not available. For example, as it is described in (Robertson et al., 1998), the students did not always use the sentence openers in the way the designer expected and sometimes the students reinterpreted the openers and they used one opener when another would have been more appropriate. Also, sometimes, the contribution (i.e. the text) accompanying the sentence opener would not necessarily correspond to the communication skill represented by the sentence opener (Dillenbourg, 2002). On the other hand, communication acts give the freedom to the students to express their contribution and to denote their intention by just selecting the desired communication act, if it is available. However, they also imply that the students understand the meaning and the significance of the provided communication acts. In any case, it is considered important to provide the widest and most appropriate range of sentence openers and/or communication acts (Dimitracopoulou & Petrou, 2003; Soller, 2001) with respect to the learning task. Usually, the CSCL environments provide a considerable number of sentence openers grouped according to the skills they intend to cultivate or according to the action they denote.

In this context, we aimed to investigate the possibility of adapting the provided "communication-scaffolding" tools (i.e. provide the most appropriate and complete set of sentence openers and/or communication acts) according to the cognitive skills that should be cultivated within the framework of the learning activity in order to promote an efficient and effective group conversation/collaboration.

3 The Experimental Study

Towards the development of a communication tool with adaptive capabilities, which will be able to facilitate/support the group dialogue and to promote the cultivation of the desired cognitive and communication skills, we conducted an experimental study. The main objective of the experimental study was to observe how the process of the discussion, between pairs of students collaborating on the accomplishment of a learning activity, proceeds and to analyse their dialogue with respect to the cognitive skills that should be cultivated. Our basic hypothesis was that the group dialogue would present similarities, as far as the structure and the use of specific phrases are concerned, in case of collaborative learning activities of different subject matters, addressing similar cognitive skills. The experimental results drew some initial conclusions about the form of the dialogue (i.e. whether it is going to be free, fully - or semi – structured) and the "communication-scaffolding" tools (e.g. sentence openers/communication acts) that are considered more appropriate to be provided, according to the cognitive skills addressed by the learning activities.

3.1 The Process

For the experimental study, we set up a collaborative environment, which was based on NCSA Habanero ver 2 (http://www.isrl.uiuc.edu/isaac/Habanero/). Habanero is a collaborative framework written in Java that includes a client, a server and a set of applications/tools. For the purposes of our study, we used only the chat tool, which provides logging capabilities and supports the record of the dialogue in log files.

As we are interested in the development of a communication tool, which will be able to facilitate/support the group dialogue in the context of collaborative learning activities concerning subject matters with different orientation (i.e. practical and theoretical subject matters), we developed collaborative

learning activities for three different subject matters - "Introduction to Programming", "Computer Architecture" and "Open and Distance Learning". A total of seven pairs of students volunteered to take part in the experimental study (i.e. two pairs of undergraduate students from the "Introduction to Programming" subject matter, three pairs of undergraduate students from the "Computer Architecture" subject matter and two pairs of postgraduate students from the "Open and Distance Learning" subject matter). The subjects were randomly paired and they had the same duties and acted equivalently during their collaboration. For the coordination of the group process, we asked one student of each pair to play the role of the "leader" and to be responsible for the record of their concluded answer to each question item/activity and for the prompt to move on to the next question item/activity.

The subjects received an overview of how the experimental study was going to be carried out including (i) a presentation of the collaborative environment, (ii) a presentation of the chat tool, (iii) guidelines about the communication skills that they need to cultivate and exhibit in order to communicate well in a team (e.g. to be polite, to wait for their partners' answer, to ask for explanations) as the subjects were not familiar with that kind of computer-based collaboration. Although, there were no constraints for the time the group members would spend to work on the learning activities, the estimated time was around 2h 30 minutes. During the experimental study, some assistance concerning the operation of the environment and especially the save of the chat log files was given.

3.2 The Collaborative Learning Activities

The design of the collaborative learning activities took into account the learning outcomes that were going to be achieved within the framework of the activities. More specifically, the learning outcomes, which may be accomplished through a set of sub-activities, may address the (Anderson et al, 2001; Mayer, 2002):

- *Comprehension level*: this level includes cognitive processes and skills, which mainly concern the students' ability (i) to remember things, that is to recognize or recall facts, concepts, etc, and/or (ii) to understand things, that is to interpret, explain and summarize the meaning of a concept, etc on their own words/by using examples, to draw inferences from facts/processes and to reason their inferences, to identify and specify the main components or key points of a construct/concept, to distinguish, classify, compare and relate concepts/facts/etc.
- *Application level*: this level includes cognitive processes and skills, which mainly concern the students' ability to specify the main steps and to follow/execute a process and/or to implement/modify a "product" according to pre-specified rules/processes or by determining its constituent parts.
- *Checking-Critiquing level*: this level includes cognitive processes and skills, which mainly concern the students' ability to check the correctness and/or the completeness of a given "product" and to reason about their opinion.
- *Creation level*: this level includes higher-order cognitive processes and skills, which mainly concern the students' ability to analyse and compose a "product", design and construct a "product" by combining various processes/methods, to plan and organize a project.

The learning activity (or each sub-activity) may include a number of question items having the form of multiple-choice questions, ordering questions, true-false questions, free-response/short answer questions, questions based on short cases, fill-in-the-blank questions, etc. The elaboration of each question item may imply the use of different support educational tools such as concept mapping tools, simulation programs, educational software, etc or navigation and information retrieval from the web.

As mentioned above, we developed learning activities for three different subject matters (i.e. "Introduction to Programming", "Computer Architecture" and "Open and Distance Learning") addressing learning outcomes of similar levels. At this stage, we focused on the first three levels of learning outcomes (cognitive skills) due to the following reasons: (i) the teaching and the learning process of all the subject matters were in progress, therefore it was very difficult to ask the students to collaborate on activities addressing learning outcomes of the highest level which implies that they have already taught and assimilated all the required educational material, (ii) the students under consideration were not familiar to collaborate using a computer-based environment, therefore we considered necessary to guide their conversation through appropriate question items, and (iii) the learning outcomes of the first three levels are more concrete, and can be easily assessed and identified in the group dialogue.

Collaborative learning activities for the "Introduction to Programming" subject matter: We developed a set of three learning activities addressing learning outcomes of the

- *Comprehension level*: the first activity was aiming to cultivate to the students cognitive skills in specifying the functional characteristics of the "while" loop and in identifying the statement used for the update of the value of the control variable. More specifically, the students had to answer to a series of question items (and to reason their answer to some of these question items) addressing the above learning outcomes, given a problem definition and its solution in the form of pseudocode.
- *Application level*: the second activity was aiming to develop to the students cognitive skills in determining and implementing the main functional characteristics of the "while" loop (i.e. initialise statement, control condition and update statement) given a problem definition and a piece of "incomplete" solution to the problem.
- *Application and Checking-Critiquing level*: the third activity was aiming to cultivate to the students cognitive skills in checking and reasoning the correctness of a given solution in the framework of a problem (checking-critiquing level) and in determining and proceeding to the appropriate modifications (application level) in order to give a correct solution according to the problem definition.

Collaborative learning activities for the "Computer Architecture" subject matter: We developed a set of three learning activities addressing learning outcomes of the

- *Comprehension level*: the first activity was aiming to cultivate to the students cognitive skills in identifying and reasoning the cache memory organisation given the different types of mapping techniques, in recalling the fields of the block address and in specifying the block and the fields of the block address for a specific main memory address.
- *Comprehension and Application level*: the second activity was aiming to cultivate to the students cognitive skills in specifying the main memory block addresses which correspond to a specific set of the cache memory, given the cache memory organisation and reason their answer (comprehension level), and in determining the steps of the identification process when the processor executes a read command from a specific main memory address (application level).
- *Application level*: the third activity was aiming to cultivate to the students cognitive skills in executing the processes of identification and placement/replacement for a series of main memory addresses and in specifying the cache memory content after each processor reference request.

Collaborative learning activities for the "Open and Distance Learning" subject matter: We developed a set of three learning activities addressing learning outcomes of the

- *Comprehension level*: the first activity was aiming to cultivate to the students cognitive skills in specifying/identifying the relationships between fundamental concepts of the subject matter. More specifically, a number of question items was given to the students in the form of correct/false propositions and the students had to identify/specify the relationship between the given concepts (e.g. the relationship between the concepts of "Distance Education" and "Traditional Education") and to reason their answers to some of the question items.
- *Comprehension and Application level*: the second activity was aiming to develop to the students cognitive skills in (i) specifying the relationships between the concepts of a given list (comprehension level), (ii) constructing a concept map concerning the central concept of "Open and Distance Education", including as many concepts as they consider appropriate from the provided list (application level), (iii) identifying the fundamental concepts presented in a given text which are directly related to the concept of "Open and Distance Education" (comprehension level), and (iv) enriching the constructed concept map with the new identified concepts/relationships (application level).
- *Application and Checking-Critiquing level*: the third activity was aiming to cultivate to the students cognitive skills in (i) checking and reasoning the correctness and the completeness of a given concept map (concerning the central concept of "Open and Distance Education"), by giving appropriate examples, according to pre-specified criteria (e.g. correctness of the provided concepts/relationships, completeness of the provided concepts/relationships/cross-links) (checking-critiquing level), and (ii) determining and proceeding to the appropriate modifications of the concept map (application level) as far as the correctness and the completeness of the depicted concepts/relationships were concerned.

3.3 The Experimental Results

As the purpose of the experimental study was to observe how the process of the discussion, between the pairs of students collaborating on the accomplishment of a learning activity, proceeds and to analyse their dialogue, recorded in log files, with respect to the cognitive skills that should be cultivated, we did not examine the correctness of their answer given to each question item/sub-activity. Instead, we

focused the qualitative analysis of the group dialogue on the form of the dialogue that was used (i.e. whether the dialogue presented some sort of structure) and on the specific phrases that were used between the group members (i.e. whether there were specific phrases that were repeated and denoted the sequence of the dialogue).

Results concerning the form of the dialogue: The messages that were exchanged between the members of each pair implied some sort of sequence, which was adapted to the context of each question item/sub-activity and subsequently to the underlying learning outcome. More specifically, the students tended to constrain their messages, to use short and clear messages and to formulate their answers by using specific phrases compatible to the question item/sub-activity under consideration (only in one case, the dialogue was quite lengthy, irrelevant to the content of the question item, due to the fact that the two students had no idea how to answer the specific question item). The above observation was clear for all activities, independently of the addressed learning outcomes and the subject matter. It seems that the question items/sub-activity, and subsequently the underlying leaning outcomes, guided the students' dialogue.

Results concerning the "communication-scaffolding" tools: The dialogue between the students of each pair was analysed with respect to the level of the learning outcomes that each activity (or sub-activity/question item) was addressing. The analysis revealed that the students tended to use specific phrases relevant to the question item (e.g. if the question item required the students to reason their answer, then they used phrases like "I believe that the answer is … because…"). The observed phrases presented similarities for those activities that were addressing learning outcomes (cognitive skills) of the same level, independently of the subject matter, verifying our initial hypothesis. We also observed phrases that were used in cases that the students asked for clarifications, for confirmation, etc.

We grouped all these phrases into three categories: (i) phrases that were explicitly related to the addressed learning outcomes (cognitive skills), (ii) phrases that facilitated and supported further the development of the communication skills, and (iii) phrases that were used exclusively from the student that acted as the "leader". The phrases concerning the development of communication skills were further subdivided into sub-categories: (i) phrases requesting for clarification, justification, opinion, information, and confirmation, (ii) phrases used for explanation, clarification, justification, (iii) phrases used for acknowledgement, (iv) phrases used for motivation, and (v) phrases expressing an emotional state and/or the need for help. In Table 1, we present indicative phrases that were observed and recorded for each one of the first three levels of the learning outcomes respectively, while, in Table 2, we present the main phrases that were used to support the development of the communication skills and phrases that were exclusively used by the "leader".

It is worthwhile mentioning that in case the learning activity was addressing cognitive skills of the Application level, then specific phrases related to the educational tool used, were observed. For example, in the case of the 2nd and the 3rd activity of the "Open and Distance Learning" subject matter, which required the construction of a concept map, the students formulated phrases like "With what concept do you propose to link the [concept]?", "Do you agree with the proposition [concept] [link] [concept]?", "Lets think how to connect [concept] to [concept]".

Also, we asked the students to mention phrases/key words, for each activity/sub-activity, that they considered useful to be provided by a collaborative learning environment. Indicative phrases that the students proposed and are not included in the tables are: "Please repeat", "Are you sure?", "I think about it", "Do you think anything else?" and concerned mainly phrases that support/facilitate the development of the communication skills.

3.4 Initial Conclusions

From the above experimental results, we drew some initial conclusions, to be taken into account in the development of the adaptive communication tool of the SCALE environment. More specifically, regarding the form of the dialogue, we concluded to use the semi-structured form of the dialogue in order to guide and support the students appropriately with respect to the skills that the learning activities are aiming to cultivate. Additionally, we believe that the semi-structured form of the dialogue can support the provision of the appropriate mechanisms in order to monitor the group dialogue, to analyse it and to provide the necessary interventions and support to the students during the activity elaboration, both at the communication and at the learning level, as well as to check and assess the students' performance in terms of the learning outcomes addressed by each learning activity.

As far as the "communication-scaffolding" tools are concerned, it becomes clear, from the Tables 1 and 2, that the range and the content of the phrases used, are not fixed and they depend on the underlying learning outcomes (cognitive skills). Therefore, we decided to adopt the sentence openers as "communication-scaffolding" tools in case of learning activities addressing learning outcomes of the Comprehension, Application and Checking-Critiquing level. The sentence opener interface will be adapted appropriately according to the level of the learning outcomes (cognitive skills) in order to facilitate the students' interaction, prevent floundering and constrain their thinking to the desired "productive" directions. More specifically, the set of the provided sentence openers, especially the one used for the support of the learning outcomes, is going to be the most meaningful and complete, containing only the necessary sentence openers. The set of the provided sentence openers that will support and facilitate the development of the communication skills, is going to include all the necessary phrases that will enable the students to ask for clarifications, to justify their opinion (in case this is not explicitly required in the framework of the activity), to ask for confirmation, etc.

Regarding the Creation level of the learning outcomes, we also intend to follow the semi-structured form of the dialogue and to use the communication acts, instead of the sentence openers, as "communication-scaffolding" tools. We consider the communication acts more appropriate, since for higher order cognitive skills, it suffices to guide/assess the students in terms of their intention/action.

Table 1: Phrases used for the Comprehension level, the Application level and the Checking-Critiquing level of the learning outcomes/cognitive skills

Phrases explicitly related to the learning outcomes of the *Comprehension level*	Phrases explicitly related to the learning outcomes of the *Application level*	Phrases explicitly related to the learning outcomes of the *Checking-Critiquing level*
I think/believe that… The answer is … because … I agree. I believe the same. Yes, you are right. No, I don't agree.	Lets add … I think we have to include … It is better to delete … I suggest to insert/modify/connect … I agree.	The answer is … because … I believe that … because … I believe that the answer is … because… I don't agree with you, because … I agree.

Table 2: Phrases used (i) for the development of the communication skills and (ii) by the "leader"

Phrases that support/facilitate the development of communication skills		Phrases used exclusively by the "leader"
Request for Clarification/Justification/Opinion/Information/Confirmation What do you mean? Why do you believe … ? Please justify your opinion. What is your opinion? What do you believe/think about? Do you agree to insert/change/delete/modify? Do you understand?		We conclude that … We both agree that … The final answer is … To summarize … Ok. We finished this question. Lets move on to the next. Do you want to continue? Let's go on again.
Clarify/Explain/Justify I mean … Because …	Motivation Why don't you say anything? That's a good idea.	Acknowledge Ok.
Emotional/Need for support I don't know the answer. Could you please help me? I have been confused. I don't understand. Wait a minute please. I need some time to think. I am not sure.		

4 Conclusions and Future Plans

In this paper, we present the results revealed by an experimental study we conducted in order to analyse the dialogue between pairs of students, with respect to the cognitive skills that the collaborative learning activities were aiming to cultivate to the students. The qualitative analysis revealed that the

dialogue presented similarities, as far as the structure and the use of specific phrases are concerned, in cases of collaborative learning activities addressing similar cognitive skills independently of the subject matter under consideration, and drew some implications regarding the form of the dialogue supported (e.g. structured or unstructured, semi-structured or fully structured messages), and the provided "communication-scaffolding" tools (e.g. sentence openers, communication acts). The exploitation of these results contribute positively to the development of a communication tool with adaptive capabilities, which will promote the development of cognitive and communication skills as well as an efficient and effective group conversation/collaboration. In the framework of SCALE, we indent to follow the semi-structured form of the dialogue and adapt the set of the sentence openers or the communication acts to the level of the cognitive skills that each learning activity is aiming to cultivate. So far, we have determined an initial set of sentence openers for the development of cognitive skills and communication skills with respect to the Comprehension, Application and Checking-Critiquing level of the learning outcomes addressed by the collaborative learning activity.

In the near future, we plan to conduct an experimental study in order to verify our hypothesis that the communication acts are more appropriate for higher order cognitive skills regarding the Creation level of the learning outcomes. Also, we plan to carry out a series of experiments in order to (i) evaluate our initial sets of "communication-scaffolding" tools and to modify them appropriately, (ii) enrich/modify these sets according to the models of collaboration which are going to be followed by the group members, and (iii) investigate the possibility of enriching the sets of "communication-scaffolding" tools with phrases/keywords related to the education tool (e.g. concept mapping tool, educational software) used in the framework of the learning activity.

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