Activity and Interaction of Students in an Electronic Learning Environment for Problem-Based Learning

Frans Ronteltap & Anneke Eurelungs
Maastricht McLuhan Institute, Learning Lab, University of Maastricht, The Netherlands

ABSTRACT This paper contains the results of an experimental study in which students used a collaborative learning tool in the time between regular meetings of a tutorial group in problem-based learning. The analysis of the learning situation for which this tool was developed, as well as the evaluation of the experiment, is based on a model of collaborative learning that covers three sections. The first is the learning environment that mediates the second section learning behaviour and the third section learning mechanisms. From the perspective of the stimulation of productivity in collaborative learning, the relation between characteristics of the problem task (learning environment) and interactions (learning behavior) was explored. In problem-based learning students formulate learning issues after a brainstorm discussion in the group. Students formulate theoretical and practical learning issues. Two research questions are presented in this study: What types of learning issues generate most interactions? and What types of learning issues generate the highest level of information processing? The first question is concerned with an analysis of the number of interactions and the second with the quality of these interactions. Practical learning issues generated more interactions, as well as a higher level of information processing. These results are discussed in the context of social factors in learning.

Introduction
This study was done in the context of the evaluation and validation of an experimental intervention in educational practice. Asynchronous communication tools were added to a curriculum where students are used to work in a problem based-learning (PBL) format, and where communication about learning issues was restricted to the meetings of the tutorial group.

Twenty-five years ago the University of Maastricht decided that PBL and its underlying pedagogical and learning principles (Barrows & Tamblyn, 1980; Schmidt, 1993; Williams, 1992) could offer the frame for the development and implementation of a series of new curricula. Initially these were small scale. An enrollment of 50 students per year and the availability of enough staff and facilities resulted in an educational situation that soon became a model for new initiatives. The present situation is that the university is confronted with an enrollment of 1,500 students per year, which is still growing. Key elements in this development were self-directed learning and small-group learning. The success of the innovative start changed slowly for the worse. In the early years students could use the library and its accommodations as an extension of opportunities to meet and discuss learning issues that
were defined in the regular meetings of the tutorial group. The distance between all members of the learning community was small enough to enable communication when this was needed.

The risk of an increase of student population is that a feeling of anonymity might grow. It was therefore not a surprise that students as well as their tutors expressed a clear need for more communication facilities. This finding was derived from a survey study (Ronteltap & Eurelings, 1996) among students and staff in two faculties of the University of Maastricht. The survey was part of the analysis of the requirements of new learning tools. Developments in the domain of information and communication technology led to reconsideration of the way in which educational principles are made operational. In this principled approach (Koschmann et al., 1993), in the definition of requirements for technological support of learning, it became clear that many of the choices that were made more than 20 years ago in the implementation phase of the curriculum could be held open to question. Regular evaluations of the curricula of the University of Maastricht showed a decreasing amount of time spent on learning by the students. The conclusion drawn from these studies was that feelings that one is part of a learning community were lost. The addition of asynchronous communication tools to the curriculum is an intervention that is studied in this paper. The next section describes the regular organization, as well as this intervention. Two questions will be presented that were answered in this research.

**Problems and Interactions as Mediators for Learning**

Two basic elements in PBL are: (1) the analysis of authentic problems in a professional context as a starting point for learning; and (2) communication among peers. At the University of Maastricht students analyze problem tasks, define learning issues for further study and discuss the progress that is made in this study. This process involves two group meetings. The first meeting is spent mainly on brainstorming and analysis and ends with a joint definition of learning issues (What do I need to know?) that will be studied in the coming period, usually 3 or 4 days. In the next group meeting, after the individual study, students report on what they found in the literature or other information sources. The function of these interactions that students perform during the learning process in this PBL format is twofold. In the first meeting students create a shared starting point for learning. They discuss the task, activate prior knowledge in a brainstorming session and elaborate on this activated knowledge. The interactions in the second meeting create the possibility of articulation and feedback. Students are asked to rephrase the subject in their own words and to elaborate on it. The shared starting point of learning stimulates the feedback that is needed.

The intervention in our study was the development and test of a shared work environment that could be used for collaborative activities in the time between the regular group meetings. Asynchronous communication was added to face-to-face communication. Learners can submit documents in this shared environment. Group members can ask questions or comment on contributions of peers and further discuss topics. The authors of the document have the possibility to revise their original documents after discussion. These texts about texts offer the cues that can influence how others can reconfigure or develop meaning (Spivey, 1997).

An important concept in our intervention is the facilitation of *productivity*. In the PBL format as implemented at the University of Maastricht, the goal of collaborative learning activities is principally process oriented. Students analyze in a group a problem task and
study the learning issues that were defined in a group discussion. This uniformity of problem and learning issues is the foundation for knowledge-oriented interactions between participants after individual study. The productivity of these interactions, however, is to a large extent dependent on the amount of time that is available for communication and the number of people in the group. This is consistent with our findings in the survey study cited above. Students expressed the need for more time for communication. Only a few of them get the possibility to speak about their work that was done in the days before, and only a small amount of time remains available for feedback on the learning process. The importance of this kind of communication is expressed by the students who indicated that they receive new impetus for learning when they explain or discuss their work. They also mentioned the value of possibilities for an informal assessment of their progress in an open and self-directed learning environment.

The addition of asynchronous communication facilities, available permanently and for unlimited use, could remove any of the above-mentioned restrictions experienced by participants. When social interaction is used as a mediator for learning, facilitating social interactions is an important step in the design of the curriculum. Learning is enhanced by conversations with those who have different opinions, backgrounds or skills; or know more about some topics and can ask perceptive, thought-provoking questions (Duffy & Cunningham, 1996; Shute & Psotka, 1996). Garrison (1994) supposes that “meaning is sociolinguistically constructed between two selves participating in a shared understanding.” This perception on the required design of a learning environment is described elsewhere as the design of “knowledge-building communities” (Scardamalia & Bereiter, 1993).

A learning tool in itself can support the productivity of the process, but how it is used and the content that will be produced by the users is influenced by more parameters than the functionality of the tool. In order to obtain a clear view of the planning and evaluation of our intervention we used a model that contains the central entities to be known for the study of productivity of small-group learning. The model combines the results of comprehensive analyses of processes in collaborative learning (Dillenbourg, 1999; Koschmann, 1996) and methods of discourse analysis (Fairclough, 1995). From the perspective of communication and collaboration between active learners a learning situation can be described and analyzed in three interrelated sections: (1) learning environment; (2) learning behavior; and (3) learning mechanisms.

The first section, “learning environment,” covers all didactic components of the curriculum that are relevant for collaborative learning and can be manipulated in the design: Goals of collaboration, cases or tasks that students analyze (authenticity, control, complexity), social parameters (status, expertise) and features of the information (medium, access, uniformity) that are used in learning, assessment of learning results (type, method) and finally the features of the learning tool.

The second section, “learning behavior,” is the core of this model. It comprises three related components that are relevant in the analysis of interactions among learners: (a) people who communicate (learning styles and attitudes, motivation); (b) user actions before and during communication (writing, reading, reacting, knowledge management); and (c) content (Ronteltap, 2001).

The third section comprises specific “learning mechanisms” that are generated by communication: Explanation (Chi et al., 1989; Kumpulainen & Mutanen, 1999), justification (Newman
TABLE 1. Example of problem task and defined learning issues

Problem task:
A 60-year-old man visits you in your general practitioner’s practice. He is worried. When he was driving home from his work, an insect flew in his left eye. When he tried to wipe it from his eye, he noticed that he could not see well with his right eye.

Theoretical learning issue: The functional anatomy of the eye

Practical learning issue: What is the differential diagnosis of loss of sight and how can it be examined?

et al., 1995), negotiation (Baker et al., 1999), reflection (Brown & Palincsar, 1989), and reconstruction (Boos et al., 1991).

The components in this model can be used in the design and analysis of collaborative learning. In two directions, either bottom up or top down. If the generation of specific learning mechanisms is aimed for, then specific learning behavior is needed. And one step further, the designer of the learning environment has to tune the situation in such a way that this behavior and these learning mechanisms will be generated. In the next section our research questions are described in this context. Only, the first two sections of this model—learning environment and learning behavior—will be addressed here.

Research Questions

In the preceding section the goal of collaborative learning is described as creating a situation in which productive interactions between learners can be generated. We made a distinction between different sections in our model of analysis and design. The relation between two sections was explored in this study: In the section of the learning environment task characteristics, and in the section of learning behavior interaction frequency as well as the level of information processing.

An important characteristic of study tasks that are used in PBL is the authenticity of the problem that needs to be solved. In many curricula these problems are presented as a case in a professional domain. However, in the way PBL is operationalized at the University of Maastricht, authenticity is not a characteristic that is strictly limited to the format of the task. In self-directed learning students analyze the case and define the learning issues for further study. These resulting learning issues vary by group or individual interests or prior knowledge. An example of this is given in Table 1.

Table 1 contains a short description of a situation that was analyzed by medical students in one of our experimental groups. After the analysis of this situation and the following discussion the group agreed on two learning issues for later study, one theoretically oriented issue and one practical. The learning issues that learners define after brainstorming can be
classified as *theoretical* learning issues (“knowing that”) and *practical* learning issues (“knowing how”). In a theoretical learning issue the acquisition of new knowledge is accentuated, often restricted to isolated facts or concepts, part of a specified discipline. Practical learning issues focus on the interpretation and application of subject matter, in the context of professional activities or part of a professional domain. In this study we explored the relation between these different learning issues with productivity.

The level of productivity of an environment can be expressed either quantitatively or qualitatively. Quantitative analyses result in frequency analyses of communication rates and patterns (Artzt & Armour-Thomas, 1992; Gunawardena *et al.*, 1997; Howe *et al.*, 1995). The first question in our research addresses the quantitative aspects of interactions in the environment: *What types of learning issues generate most interactions?*

Our next question addresses the quality of these responses. Although the productivity of collaborative learning is dependent on the accessibility and functionality of a communication platform, it does not guarantee that these interactions in themselves have the quality required for *learning*. Asynchronous learning is directed by a written discourse. These writing activities might have a positive effect on the level of processing of the information that was studied. In PBL active processing of information is required by students. A tutor who coaches the group will discourage his students from reading out literature or personal notes. Articulation is promoted by asking students to express their findings and knowledge in clear words. In order to answer our research question as to whether participants in an electronic learning environment actively process the studied information, all contributions in the database will be evaluated on the level of “cognitive activity.” Technically it is possible to compose documents by “copying & pasting” information from external information sources. This demands a low level of cognitive activity. Summarizing this information demands more activity of the authors, and writing an original contribution in their own words is evaluated as the highest level of processing. Based on this perspective our second research question is: *What types of learning issues generate the highest level of information processing?*

Both questions explore the productivity of the learning environment. The first question addresses the frequency of the interactions, a basic condition for learning in a social environment. Our second question addresses the level of information processing by the learners.

**Method**

This study was performed in a series of studies on the results of experiments with the POLARIS learning tool that was developed to facilitate collaborative learning in different curricula of the University of Maastricht. A group of tutors and students participated in the development of the tool, as well as in the preparation of those experiments. The overall goal of the POLARIS project was to explore the possibilities of combining synchronous and asynchronous communication during the learning process. Different methods were used in the evaluation of the results. The content of the work environment that was produced was analyzed, group interviews were organized that were recorded, and
the tutors were interviewed. In this study the content of the work environment (initial documents and subsequent reactions) were analyzed.

POLARIS offers the learner a shared work environment where written reports can be submitted about learning issues that were defined during the face-to-face meeting. The members of the group could work in a mix of synchronous and asynchronous collaboration. After the face-to-face meeting, when the learning issues were defined after the brainstorming discussion, the secretary of the group submitted these set of learning issues to the system. From that time, until the next face-to-face meeting, the group could meet in POLARIS. Students were asked to write initial reports about separate learning issues and to give feedback on the work of others. When a report was submitted, a learner was automatically authorized to read the work of their fellow students. The group environment was available for the users 24 hours a day via a connection between students’ homes and the campus server. The experiments started with technical instruction about the features of the tool.

Two experiments were analyzed in this study. One group of the third class in the Medical School (n = 9) and one group of the fourth class in the Law School (n = 7) worked with the system in one block period (6–8 weeks). This repeat of the experiments was planned in order to determine whether there are differences in the use of this tool between the curricula in the University of Maastricht.

In each experiment two different domain experts were asked to analyze independently the content of the work environment that was produced in the weeks before. First they were asked to classify all learning issues that were defined by the participants’ two clusters: theoretically oriented versus practically oriented learning issues. The experts were asked to write a report on the results of this analysis. These reports were compared and the experiment leader determined the level of agreement of the content analysis. The reports were discussed in a joint meeting of experts and experiment leader. When differences in the evaluation occurred, arguments for and against were discussed and the discussion was closed with a decision by common consent. The topics about which no agreement could be reached were put aside.

For the analysis of our first research question concerning the level of productivity—the number of interactions between the learners—all initial documents (start of a discussion thread; branched view on content of database, organized by initial documents and subsequent reactions at different levels) and the reactions that form a part of a thread were counted. The content validity of the documents was also checked in the analysis. Reactions that did not contain a relation concerning the content of a preceding document (remarks about different topics) were also put aside.

The level of “cognitive activity” in order to answer our second research question was measured by thorough examination of each separate initial document in a discussion thread. The similarity between a submitted document and the information sources (books, articles) that were used in the composition of the document was ranked. The references to the information that was studied were given in the reports. The experts were familiar with the content of that information. The lowest-level documents were “Copy & Paste” documents. They contained predominantly verbal or visual information extracted from one or more digital information sources. The content of a second-level document is predominantly a summary of the content of a specified information source. Documents were classified as an original contribution when a personal structure was found, either interpretations or reflections about the content, and in most cases including multiple references.
Results

Our first research question addresses the relation between the defined learning issues in the group and the number of interactions during asynchronous interaction. The results of this quantitative analysis are presented in Tables 2 and 3.

The columns in the tables differentiate between the two classes of learning issues. The medical students (Table 2) formulated 27 theoretical and 15 practical learning issues for study. The 27 theoretical learning issues resulted in 111 initial documents, which were followed by 31 reactions. The level of interaction was defined as the ratio between reactions and initial documents. Theoretically oriented documents were in fewer cases the start of a dialogue (reactions/documents = 0.28) than their practical counterparts (reactions/documents = 0.45). The law students’ database showed a similar difference: 0.53 versus 0.63. With respect to our first research question it can be concluded that in the medical group and in the law group proportionally more interactions about practical documents were observed during collaboration.

The level of the composed documents, relevant for answering our second question about the relation between learning issues and the level of information processing of learners, can be seen in Figs. 1 and 2. Comparison of both figures reveals that law students generate relatively more practical learning issues than medical students. Both groups composed only a few “copy & paste” documents. Furthermore, it was found that the nature of learning issues and the level of cognitive activity are related. In the medical group 30% of the documents about theoretical issues were judged as original documents, while 45% of the documents in the category of practical learning issues were classified as original documents. In the law group this proportion

<table>
<thead>
<tr>
<th>Learning issues</th>
<th>Theoretical</th>
<th>Practical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documents</td>
<td>111</td>
<td>144</td>
</tr>
<tr>
<td>Reactions</td>
<td>31</td>
<td>77</td>
</tr>
<tr>
<td>Reactions/documents</td>
<td>0.28</td>
<td>0.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning issues</th>
<th>Theoretical</th>
<th>Practical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documents</td>
<td>110</td>
<td>144</td>
</tr>
<tr>
<td>Reactions</td>
<td>69</td>
<td>77</td>
</tr>
<tr>
<td>Reactions/documents</td>
<td>0.63</td>
<td>0.53</td>
</tr>
</tbody>
</table>
was 42% versus 63%. This finding brings us to the conclusion that practical learning issues, those that lead to learning and acquisition of knowledge in the context of the development of professional expertise, result in more active processing of subject matter.

**Discussion**

In both analyses of the shared work environments a relation was observed between the nature of the learning issues, being the base for the documents which were composed, and two aimed functions of the communication tool: Stimulation of active learning behavior and interaction

![Graph showing frequency distribution of cognitive activity in documents related to theoretical or practical learning issues (medical curriculum).](image1)

![Graph showing frequency distribution of cognitive activity in documents related to theoretical or practical learning issues (law curriculum).](image2)
between learners. Practical learning issues result in deeper processing of information than theoretical learning issues. Reports about practical issues also cause more interactions between participants in the virtual learning environment. However, this observation was made twice in small groups with a limited number of students. In new experiments we will repeat these observations in order to find evidence for relations between the learning environment and productive learning behavior.

This study was part of a series of validation studies of the POLARIS learning environment and exploration of the potential added value of the tool. This tool aims to support learning activities in a problem-based curriculum. The combination of synchronous and asynchronous communication results has strong effects on the practice of collaborative learning. Writing for asynchronous communication may lead students to a deeper level of information processing when they compose documents that represent their personal knowledge based on study of the literature. Compared to the usual work procedures of tutorial groups, the facility of submitting reports independent of time and place offers possibilities for additional interactions and feedback. The learning environment that was tested meets the requirements from a social-constructivist perspective. In PBL the learning process is directed by the analysis of problem tasks and the definition of learning issues by students (self-directed learning). In this process of defining learning issues students make choices. One of the options is the contextualization of learning. The data in this study suggest that, if cognitive activity and interaction are goals in the design of our learning environment, it is advisable to learn in the context of professional activities.

In this study an effect of the nature of learning issues on subsequent active learning behavior and interaction was found. Given the fact that the data were collected in a few observations (a limited series of tests in different study years, different curricula and only two tutorial groups), continuation of research to collect data to confirm the conclusion above is necessary. A second comment might be that in parallel observations, of the same groups but not part of this study as described in the Method section, we found that students need time to learn this method of collaborative work, despite all the experience they already had in the usual group work. Our volunteers were not used to “writing” about their study and mentioned some hesitation in the experience in responding on documents of their peers. In both cases students needed a period of getting accustomed to the tool and its functionality within the experimental period. The potential possibilities of this learning environment were insufficiently used. These additional comments were made in group interviews after the experiments. In these interviews the participants also expressed that the regular schedule of “group meeting–three days of individual study–group meeting” imposed limitations on the optimal use of the system.

An essential aspect of this intervention is an extension of collaborative work facilities as a mediator for learning. Students are asked to accept the responsibility for the learning process of a community. Supplementary evaluations in group interviews of impressions and feelings about the experimental learning process showed evidence that the situation was fundamentally changed. A simple addition of asynchronous communication facilities, available in the time between regular group meetings, turned out to be a transformation of the complete learning environment and the learning process. The process of writing itself took more time than usual and resulted in more profound learning. Learners realized that texts in a shared work environment are more than a personal representation of the information that was studied. Texts also have a function in a discourse; they are the input for extended learning. The regular
communication in group meetings is restricted to brainstorming and discussion at a much more elementary level. Individual weaknesses and deficiencies, sometimes motivational aspects, dominate interactions in face-to-face meetings. In these experiments students experienced collaborative application of knowledge, reflection and restructuring. Our findings fit with Wertsch’s theoretical framework of “Mind as Action” in which the success of the reciprocal teaching method is understood as a reorganization of “participant structure” (Wertsch, 1998). When rights, roles and responsibilities of participants change, discourse will change. Our findings support this view. The participants in our experiments experienced a new method of communication that affected their level of activity.

In the design and evaluation of our experiments we used a model that covers three dimensions of collaborative learning. A relationship was found between the sections of our model. The types of learning issues (theoretical or practical) and the type of knowledge that is acquired (“knowing that” or “knowing how”) are entities of the first section that affect the productivity of interactions that are part of the second section. We conclude that in the context of curriculum design social interaction can be initiated by constructing specific learning tasks. We also found a relation between the types of learning issues and the quality of the interactions. Practical learning issues effected a higher level of processing of information. In that perspective our analysis of the effects of the functionality of our environment and the social contribution to the quality of knowledge acquisition among participants is still superficial. A theory of mediated action might offer a framework for supplementary analyses of data between and within the sections of our model. The process of “internalization” as “appropriation,” defined as “a process of taking something that belongs to others and making it one’s own” (Wertsch, 1998, p. 53) is essential for our further analysis. A principle goal in the development of our communication tool was to create an environment that can function as a tool for social elaboration on knowledge. An in-depth content analysis of initial documents and subsequent reactions is needed to study the learning mechanisms that are important for this process of appropriation.

REFERENCES


Correspondence. Frans Ronteltap, Maastricht McLuhan Institute, Learning Lab, University of Maastricht, P.O. Box 616, 6200 MD Maastricht, The Netherlands. E-mail: F.Ronteltap@mmi.unimaas.nl

Frans Ronteltap is Associate Professor in the Maastricht Learning Lab. He is involved in the development and research of learning tools in the curricula of the University of Maastricht.

Anneke Eurelings is Program Director of the Transnational University Limburg.