Exploring Interaction Behaviour and Performance of Online Collaborative Learning Teams

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Abstract. Studying and analysing the collaborative behaviour of online learning teams and how this behaviour is related and affects task performance is a complex process. This paper presents an integrated approach that analyzes the participatory attitudes of group members in collaborative learning activities (group functioning) in relation to the individual and group learning outcomes (task performance). To that end, we first provide principled criteria and methods for evaluating collaborative problem-solving situations and then we identify different group types in terms of their degree of success at group functioning and task levels. Our objective is two-fold: assessing the effectiveness and adequacy of the evaluation criteria and methods, and exploring the interaction behaviour of different collaborative group types with respect to their performance.

1 Introduction

Research in Computer-Supported Collaborative Learning (CSCL) explored the types of problems that may result from insufficient group interaction and support (see e.g. [1]). Several research approaches have been developed for observing, analysing and assessing collaborative learning interactions as well as for developing methods and tools that provide guidance and support to on-line learning teams (see [2,3,4]). Common to the most of these approaches is their development and testing on a rather small sample of on-line learning groups on an experimental basis, focusing on the analysis of the participatory and social aspects of collaborative learning processes. Our research proceeds one step further by explicitly distinguishing two evaluation levels: the group functioning and the task performance. The former examines the way a group of students functions as a cohesive collaborative learning team. The latter assesses students' individual and group problem-solving capabilities and performance as concerns task accomplishment. Our work also relies on real, on-line collaborative problem-solving situations that form part of three distance learning undergraduate courses ([5]).

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The aim of this work is to study the relationship between the interaction behaviour (group functioning) and the learning outcomes (task performance) of a group and its individual members. The first step toward the analysis of collaborative practices is the establishment of evaluation criteria to assess group functioning and task performance. This leads to the classification of learning groups into specific categories. Finally, the results of the evaluation process are further analysed with the students' learning contributing actions in order to determine the relation of the students' collaborative behaviour to their learning success and, to assess the effectiveness and accuracy of the evaluation approach itself.

2 Research Method

Over 300 students and 6 tutors participated in three collaborative learning experiences during four months in Winter 2002 semester. All practices were carried out mostly asynchronously; synchronous interaction occurred in few specific cases of decision-making. All asynchronous collaborative interactions took place on the Basic Support for Cooperative Work (BSCW), a groupware tool that enables asynchronous/synchronous collaboration over the web [6]. This research derives its theoretical basis from existing collaborative learning theories and models such as Distributed Problem-based Learning [7], Learning-by-Design and on fundamental aspects that have been identified in collaborative learning studies. One of these, the Time, Interaction and Performance theory (TIP) presents a useful theoretical framework [8]. Thus, the TIP theory states that successful groups always undertake three functions at the same time: (i) production function; (ii) group well-being; (iii) member support. Sfard [9] talks about the two main metaphors of learning: (i) the acquisition and (ii) the participation metaphor. The first interprets learning in terms of the acquisition of something whereby the latter deals with learning as becoming a participant. Further, for effective collaborative interaction, it is essential to ensure that each member receives the help he needs from his peers [10]. Finally, the Collaborative Learning Model of [3] classifies effective collaborative learning teams into five categories: (i) participation, (ii) social grounding, (iii) active learning conversation skills, (iv) performance analysis and group processing, and (v) promotive interaction.

Our research takes all previous work a step further by: **(a)** integrating and exemplifying the above fundamental notions into principled evaluation criteria; **(b)** establishing specific evaluation methods for assessing individual and group performance at task and group functioning levels; **(c)** identifying categories of learning groups, based on group performance; and **(d)** setting the basis for the development of a framework for analysing and assessing group interaction.

3 The Evaluation Approach

The first step of our approach is to define adequate evaluation criteria and show how they are related to the above collaborative learning theories and models.

In this way, we obtain sound, effective and principled criteria at two distinct evaluation levels. This is an important step to build a systematic and efficient evaluation approach.

3.1 Defining Principled Evaluation Criteria

The evaluation is performed at two levels: problem solving (PS) and group functioning (GF). As for the first, we tracked groups and members' problem-solving achievement by assessing the following aspects that constitute our evaluation criteria for this level. For each criterion we annotate the exact study that is derived from and is described above (for instance, - [9](i) refers to Sfard's acquisition metaphor): **PS1:** The students' individual and group learning outcomes (acquisition metaphor) - [9](i); **PS2:** The students' contributing behaviour during task realisation (production function - [8](i), and use of active learning skills) - [3](iii); **PS3:** The students' individual and group ongoing/final performance in terms of self-evaluation - [3](iv).

As for the latter, we evaluated the way group members functioned as a cohesive learning team, and whether they achieved to learn how to work together. Group functioning is measured through: interaction - [8](ii), which is also associated to the participation metaphor - [9](ii), and support - [8](iii). In order to define specific evaluation criteria related to the collaborative interaction we take into account the aspects identified in [3] and adapt them to our purposes. Specifically, interaction can be characterised and measured by the following parameters: **GF1:** Active participation behaviour - [3](i); **GF2:** Social grounding skills (well-balanced contributions and role playing) - [3](ii); **GF3:** Active learning interaction skills that facilitate the group's well-being function - [3](iii); **GF4:** Group processing (groups perform a self-evaluation on their progress and performance as to whether each member learnt how to interact and collaborate more effectively with his teammates) - [3](iv).

Additionally, social support is determined by exploring Webb's 5 criteria that ensure promotive interaction in a group ([10], [3](v)). Due to the courses goals and the complexity of the whole evaluation process, the assessment of the students' problem-solving capabilities and learning outcomes represents the 80% of the final grade, while group functioning gets the 20%.

3.2 Evaluation Methods for Individual and Group Performance

A collaborative problem-solving situation comprises of at least four sub-problems (phases), each of which has to be completed over a period of 3 or 4 weeks, and is completely evaluated. We present each evaluation method in turn and discuss the evaluation criteria it satisfies.

First evaluation method: tracking new collaborative activities. The tutor uses a specific BSCW functionality (the awareness information) to perform a continuous tracking of the new collaborative activities in a group's shared workspace (criteria PS2 and GF1). The BSCW distinguishes and generates four generic types of events (actions) related to an object: (a) Create events; (b) Change

events; (c) Read events; (d) Move events. The create and change events basically indicate active involvement to problem-solving and we call them active learning contributions. The read and move actions indicate a receptive and organisational behaviour, resp. We call the latter information processing contributions.

Second evaluation method: tracking of individual (vs. collaborative) contributions. This method uses a specific software tool, called "BSCW Event Extractor" that extracts BSCW daily log files and filters this data according to desired parameters defined by the tutor's needs for tracking and assessment. The tutor is able to measure group functioning and problem-solving performance by determining the learning activities of group members, quantifying the amount of events per member, and examining whether a balanced contribution of action types exists (criteria PS2, GF1 and GF2). Moreover, a group coordinator supplies the tutor with important information about the members motivation and possible conflicts requiring the tutor's support (criterion GF3).

Third evaluation method: summative assessment of learning outcomes. The tutor assesses groups' learning outcomes at the end of each phase (criterion PS1), when each group delivers the tutor the solution of the current sub-problem.

Fourth evaluation method: group self-evaluation. At the end of each problem-solving phase, each group elaborates and delivers a self-evaluation report in which students assess their participation and performance (criterion PS3). This report also tells how well the group worked as a collaborative team, and whether they learnt how to collaborate effectively (criterion GF4). Moreover, members have the chance to state whether they received the desired help and encouragement by their teammates when needed (group social support).

Fifth evaluation method: final individual self-evaluation. At the end of the whole process, each student elaborates a self-evaluation report (criterion PS3).

3.3 Categorisation of Collaborative Learning Groups

Our evaluation approach also makes a first step towards identifying categories of learning groups according to their performance at problem solving and group functioning levels. The tutor assigns each group a mark on a 5-point scale at both levels: A (excellent), B (fairly good), C+ (good or passable), C- (not passable), and D (fail). The combination of the two marks determines the different group types. Not all mark combinations were considered since they did not occur in our experiences. We propose the following initial categorisation (the marks in parenthesis correspond to problem-solving and group functioning resp.):

Ineffective: The group fails at all levels of collaborative learning (C- or D/C- or D).
Sufficient: The group's overall performance is just admissible (C+/C+).
Non-rewarded: Good performance at functioning level but it was not paid back with proportionally good learning outcomes (C+/B) or (B/A).
Successful but imprecise: Fairly good learning outcomes but its interaction behaviour and support was rather weak and imprecise (B/C+).
Well-considered: Fairly good task learning results by a group conforms to its good outcomes as regards collaboration skills and effectiveness (B/B).

Fairly successful but somewhat deficient: Very good learning outcomes but it does not achieve an equally effective collaborative interaction and support (A/B).
Effective: Very good performance at problem-solving and group functioning (A/A).

4 Data Analysis from a Collaborative Problem-Solving

In order to assess the effectiveness and adequacy of the evaluation approach and to explore the groups' interaction behaviour with respect to their performance, we carry out an empirical analysis of real interaction data from a collaborative problem-solving situation. Since the analysis concerns groups' interaction behaviour, the results found are connected to evaluation criteria defined at the group functioning level (GF) in the previous section and thus to the collaborative learning studies of Sect. 2. Data analysis comes from an undergraduate distance course that involved 186 students and 3 tutors, forming 31 groups of 6 members. Groups collaborated on-line to carry out a real case study. The results presented here describe trends in a small data sample, and do not imply statistical significance.

4.1 Interaction Attitudes and Performance of Individual Members

Due to its particular interest, we chose a non-rewarded group type evaluated with a C+ and B marks at problem solving and group functioning, with the aim of examining whether the participation and contribution behaviour of its members is consistent with their learning outcomes. Based on the tutor's assessment, apparently the group functioned fairly well as a collaborative team. However, the performance of its members at task level was not equally effective, since they were not rewarded with equally good learning outcomes.

As shown in Fig. 1, the learning achievement of some members (fca, rsa, mmo) was just sufficient (C+), where others achieved better outcomes (imo: A;

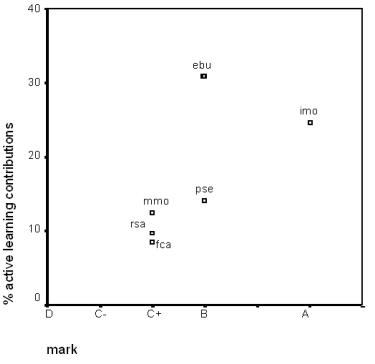

Fig. 1. Active participatory attitudes of group members vs. learning achievement.

pse, ebu: B). It is interesting to find out reasons for this "contradiction": quite effective collaboration vs.heterogeneous learning. Fig. 1 shows the assessment mark obtained by each member with respect to their percentage of active learning contributions (create + change) - criterion GF1. It could be normal to expect that the more active a learner is the better learning outcomes achieves. However, as shown in Fig. 1, this is not the case for the members of this group. For instance, student "ebu" is attributed the highest percentage of active learning contributions (more than 30%); however, he obtained a final B mark, the same as student "pse" who realised just the 14% of active learning contributions. In contrast, student "imo", whose active contributions rose to 24,6%, achieved an A mark. The figure also shows that the active learning contributions of group members were not well balanced - criterion GF2. There are clearly two members, "ebu" and "imo" that stand out among the others. We provide a more detailed analysis of all action types performed by each member in Fig. 2 (in the table, the first line and column represent the actions types and students resp. The entries (e.g., 9.52) indicate the percentage of an action type performed by a student).

	Change	Create	Move	Read
fca	9.52	7.64	0	19.78
rsa	4.76	14.65	0	15.11
mmo	14.28	10.19	2.24	9.51
pse	9.52	18.47	10.11	13.25
ebu	38.09	23.57	85.39	24.81
imo	23.8	25.48	2.24	17.54

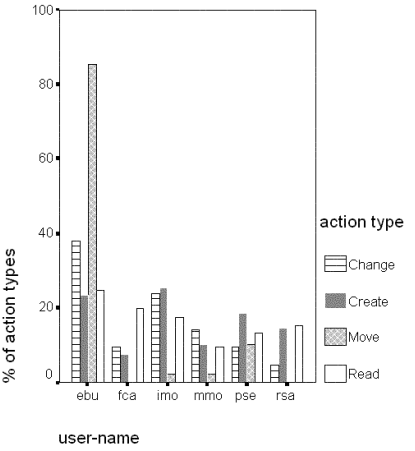

Fig. 2. Percentage of action types performed by a student.

Fig. 2 clearly shows that group behaviour is not homogeneous - criterion GF2. Among all actions, only the read one seems to be well balanced for all members. In contrast, the members' contributions regarding the rest of the actions are quite heterogeneous. We observe that student "ebu" stands out among all other members as concerns all actions except the create one. In fact, "imo" contributed the most (25,48%) of the create actions, though "ebu" is also quite close to this score. However, "ebu's" very high score of move actions (85,4%) shows that he spent much of his time in duties related to management and maintenance, probably at the expense of quality contributions. Clearly, a group member ("ebu") presents active interaction skills by dedicating a lot of effort to the group's well-

being function in contrast to the other members who either contribute a little ("mmo" and "imo") or nothing ("fca" and "rsa") to this aspect (criterion GF3).

In order to comprehend and decode the participation and contribution behaviour of each student better, we need a more refined analysis, given in Table 1.

Table 1. Percentage of objects created, modified or read by each student.

	obj. type	fca	rsa	mmo	pse	ebu	imo
Create	document	8.33	20.83	11.46	13.54	18.75	27.08
	note/s	11.11	5.56	11.11	27.78	22.22	22.22
	folder	0	0	0	0	80	20
	others	0	5.26	0	31.58	36.84	26.31
Change	document	10.53	5.26	15.79	10.53	31.58	26.31
	note/s	0	0	0	0	0	0
	folder	0	0	0	0	100	0
Read	document	17.06	17.06	9.36	15.05	22.07	19.40
	note/s	23.11	12.60	9.66	10.92	28.57	15.13

Interpretation of all the above data reveals that the distinguished performance of "ebu" regarding both active learning and information processing contributions begins to fade at a closer look of his real actions. In fact, much of his create and change contributions clearly focused on process management rather than on learning tasks. In this sense, "imo" (who got the best mark) seems to be more interested in his own learning mission and achievement, quite selective regarding reading, and rather indifferent and unsupportive to procedural matters (he contributed only the 2% of the group's move actions). The latter is also true for the rest of members, except "pse" who contributed to management tasks (10% of move actions; 31,6% of create "others" that include planning and preparation of virtual meetings, group agenda, etc.). This member was also quite active in creating though he focused more on message creation, while his reading others' contributions was not very positive (13,2%). His good mark (B) was mostly due to his quality rather than quantity of task contributions.

Yet, contrary to the fairly good percentage of create and read actions of "rsa" (around 15% each) and the creation of more than 20% of the group's documents, "rsa" was not recompensed by good learning outcomes (got a C+). A qualitative analysis is clearly needed to examine the quality of "rsa" contributions. This is a typical case of an implicated personality, that is, a person who intervenes in group work but does not interact: his involvement in interacting with others was very low – around 5%. Finally, as regards the other two members with a C+ mark, we observe that "fca" was actually a passive reader, whereby "mmo" was more active in editing documents and not very interested in reading.

Assessing the Evaluation Approach. This analysis shows that the real participation and contribution behaviour of the members of this group was quite irregular. On the one hand, this means that the tutor's assessment of group functioning (B

mark) was not quite right; the group members were far from achieving a fairly effective and supportive collaboration. That is, the group did not deserve a B mark at functioning level. We certainly need to develop better and more intuitive support means to help both the members to figure out their deficiencies and decide what behaviours to change (or maintain) and the tutor's assessment. This is an eminent goal of our research.

On the other hand, the evaluation approach proved to be fair regarding each member's mark; our criteria and methods managed to take into account the differences/similarities detected in the contribution behaviour of each member regarding task realisation. Since problem-solving evaluation represented the 80% of the final grade, the inconsistency detected at group functioning assessment did not affect the individual final mark. A detailed analysis will enable us to better predict the group behaviour and individual attitudes of its members as far as task achievement and good functioning concerns.

5 Conclusions and Ongoing Work

The evaluation of a learning group and its members who participate in long-term collaborative problem-solving activities at a distance is a complex process. In order to assure the success of the learning process, it is crucial to determine evaluation criteria and methods that allow to correctly assess the individual and group performance.

In this work we provided several evaluation methods associated to principled evaluation criteria and contrasted with real analysis data gathered from different groups' workspaces so that to assess their effectiveness. Our analysis can serve as a starting point to identify the weaknesses (types of problems and needs that may arise in a collaborative learning situation), and the strengths (the specific characteristics or patterns of effective collaboration) shown in each group type. The next steps involve gathering and analysing more data to strengthen the claims made and probably generalising these claims to a methodological framework for effective collaborative learning.

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