Collaboration as an opportunity for individual development

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***Abstract*— In this paper we explore how specific individual and group characteristics may influence students' contribution in a collaborative task as well as their progress after collaboration. An empirical study is described, where students worked on concept mapping tasks, individually and in groups. Assessing, analysing and comparing the individual and group concept maps constructed, specific influences were identified among them. Based on these data, dependences among individual and group characteritics such as knowledge and style, with individual progress were investigated. Finally, we discuss how factors that reflect individual and group characteristics before, during and after collaboration may inform the learner and group model of the adaptive concept mapping environment COMPASS.**

Keywords- group to individual influence; individual to group influence; learning style; learner model; group model; personalisation;

I. INTRODUCTION

In the area of collaborative learning, much research has been conducted on group effectiveness focusing on collaboration and significant links have been identified between quantitatively coded interactional data and outcomes, such as quality of group performance and collaboration. Although learning in groups is considered to have positive effects on individuals [16] [13] [3], just a few studies have been performed about the impact of groups on individuals' achievement outside the group [12] [5]. In this line of research, a quite interesting issue is how a collaborative session may be affected by each individual student and how it may affect each member of the group. To this end, it is necessary to investigate what individuals bring with them into the collaborative setting, how they affect it, and what they take away from such an interaction.

Following the individual differences and collaborative learning literature [15] [10] [2] [5], individual characteristics such as style or background knowledge, as well as variations in group inputs such as member abilities/ skills/relations/roles/styles, may foster different types of interaction and outcomes. Aiming to extend research on collaborative learning from the individuals' perspective, in this paper influences that individual/group style and knowledge may have on individual progress are investigated. To this end, factors that reflect style characteristics and performance at individual and group level are considered and dependences between them are explored. Although a variety of dependences among the individual and group characteristics is worthwhile to be investigated, in this paper we focus on the following questions:

- how individual background affects students' contribution to the group outcome and individual progress in a collaborative session,
- how group synthesis based on style may affect individual progress.

The way such information may inform the learner and the group model of an adaptive concept mapping environment is also discussed.

II. RESEARCH CONTEXT

Different factors have been considered as contributing to learning effectiveness and interaction dynamics in a collaborative learning setting such as type of task, learner characteristics/preferences, context including learning environment and type of communication (e.g. synchroous or asynchronous), organizational conditions, mode of interaction adopted.

Among the few studies that focus on group-to-individual transfer, Olivera and Straus [5] investigate how group collaboration influences subsequent individual performance. In their work, factors that are considered important are *group inputs* (e.g. member skills, group structure, and organizational resources) that influence *group interaction* which in turn affects *outcomes* (e.g. group performance), and fosters both *cognitive and social processes* that influence *individual knowledge acquisition* and subsequent *individual performance*. Stonayova and Kommers [14] investigated three different modes of group interaction (i.e. distributed, moderated, and shared interaction) in the context of concept mapping tasks, resulting that learning effectiveness is significantly infuenced by the interaction scenario adopted and that the shared mode is the most effective one. In this work, several factors are considered as reflecting individual and group 'learning effectiveness' such as *fluency*, *enrichment*, *knowledge acquisition*, *retention*, *creativity*, *individual-to-group transfer* that reflects the individuals inputs in the group solution, and *group-to-individual transfer* that reflects the knowledge that is transferred from the shared group cognition to the individual cognition. Also, Khamesan and Hammond [1] based on the work of Stoyanova's and Kommers' [14] consider learning effectiveness as to be also influenced by individual-to-individual transfer, rejection at group level, rejection at individual level, and overlapping.

In the study, presented in this paper, we build on and expand further the above-mentioned ideas investigating learning effectiveness through the lens of the complex interplay between learner / group characteristics. We adopt most of the factors considered as indicators of learning effectiveness in the above studies and seek for dependences among student/group characteristics such as knowledge and style, and individual progress.

III. Empirical Study

In this empirical study, a collaborative script has been adopted in which individual and collaborative tasks are interweaved. Since, one group session is considered sufficient for group-to-individual transfer [18], the study was organized in three phases. In the pre and post collaboration phases, students worked on individual tasks, allowing us, in the pre collaboration phase, to identify their background knowledge and their progress in the post collaboration phase. In all the three phases, students had to work on concept mapping tasks, constructing two individual products (pre and post products) and a group product working in groups.

Concept mapping was adopted due to the expressive power of concept maps (CM) in externalizing the cognitive structure of learners and their appropriateness as a collaborative learning task [8] [20] [14]. Concept maps use a simple formal convention: nodes, links and labels on the links, organized in a structure (hierarchical or non-hierarchical) to reflect the central concept of the map; nodes represent *concepts*, and links, annotated with labels, represent *relationships* between concepts [7], whilst the triple Concept-Relationship-Concept constitutes a *proposition*, which is the fundamental unit of the map.

A. Method

Thirty-four 4th year undergraduate students (12 female and 22 male) enrolled in a semester-long course entitled "Didactics of Informatics" at the Department of Informatics and Telecommunications, University of Athens, participated in this study in order to earn extra credit toward their course grades. Students were asked to complete the 80-item Honey and Mumford Learning Styles Questionnaire (LSQ) [17]. In particular, the LSQ determines learning preferences following the Honey and Mumford (H&M) style categorisation: Activist (A), Reflector (R), Pragmatist (P), Theorist (T). Having as a target the investigation of influences of specific factors at individual and group level and due to the complexity of the interactions that take place in large groups, small size groups were formed based on students' learning style as depicted in Table I.

TABLE I. GROUP FORMATION BASED ON STYLE: GROUP STYLE IS CHARACTERISED BASED ON THE LEVEL OF HOMOGENEITY OR HETEROGENEITY OF THE GROUP

Groups	***Students***	***Individual Style***	***Group Style***
Group1	Std1.1	A	Heterogenous
	Std1.2	R	
	Std1.3	T	
Group2	Std2.1	R	Heterogenous
	Std2.2	Average	
Group3	Std3.1	R	Homogeneous
	Std3.2	R	
Group4	Std4.1	A	Heterogenous
	Std4.2	R	
	Std4.3	T-R	
Group5	Std5.1	A	Heterogenous
	Std5.2	R-A-T	
	Std5.3	T-R	
Group6	Std6.1	A	Heterogenous
	Std6.2	A-R	
	Std6.3	T-R	
Group7	Std7.1	A-R	Homogeneous
	Std7.2	A-R	
	Std7.3	A-R	
Group8	Std8.1	A	Homogeneous
	Std8.2	A-R	
	Std8.3	A-R	
Group9	Std9.1	A-R-P-T	Heterogenous
	Std9.2	P-A	
	Std9.3	T-R	
Group10	Std10.1	A-R-P	Heterogenous
	Std10.2	T-P	
	Std10.3	T-P	
Group11	Std11.1	A-R-P-T	Homogeneous
	Std11.2	A-R-P-T	
	Std11.3	A-R-P-T	
Group12	Std12.1	A	Homogeneous
	Std12.2	A	
	Std12.3	A	

Specifically, students were organised in twelve groups based on their styles (ten groups of three students and two groups of two students) so that groups of different level of homogeneity and heterogeneity were formed. Students were characterised based on their stronger preferences, i.e. a student may be characterized as Activist & Reflector (A-R) in case s/he depicts strong preference on both styles.

The study was structured in three phases:

Phase A - Students work individually developing their own products (individual pre products). During this phase, students were given an individual concept mapping assignment as an in-class activity; students were quite familiar with the concept mapping technique, as they had worked out several concept mapping tasks during the semester. Students were asked to act as tutors preparing a concept map (CM) (pre-map) with the COMPASS environment (COncept MaP ASSessment) [4] about the central concept of "Computer Storage Units" for a high school class (a list of 22 concepts and 20 links was provided whilst students were allowed to add up to 5 new concepts).

Phase B **-** *Students work in small groups developing a group product.* Students organized in small groups in order to jointly construct a CM for the same central concept. In this case, students were asked to act as tutors and collaborate with their colleagues for the same target. For the group map construction, students used COMPASS and consulted their individual CMs constructed previously. They had at their disposal the same list of concepts given in Phase A and they were allowed to add up to 5 new concepts in the group map.

Phase C - Students work individually developing their own products (individual post products). Lastly, students worked individually to construct a CM (post-map) on the same topic (using the same list of concepts, whilst they were allowed to add up to 5 new concepts).

B. Data Collection and Analysis

Students' pre, group and post CMs were collected, assessed, analysed and compared. In particular, each student constructed two individual CMs (one pre-map at Phase A and one post-map at Phase C) and participated in the construction of a group CM in the collaborative session of Phase B. The propositions of the maps collected, reflect students' beliefs on the particular central concept. Initially, all the propositions were assessed based on an assessment scheme that focuses on the accuracy of each proposition following the relational assessment method for concept maps [6] [11] [19]. According to the particular assessment scheme, each proposition is characterized as *Complete & Accurate Belief (CAB)*, *Partially Accurate Belief* (PAB) and *False Belief (FB)* and appropriate weights are assigned to each category, i.e. 3 points for each CAB proposition, 1 point for each PAB and -1 points for each FB. As illustrated in Figure 1, each proposition of the pre CM of Student 2 of Group 7 is characterized as CAB, PAB or FB. In particular:

- *False Belief (FB)* is used for non-scientific beliefs. For example the proposition 'Magnetic storage units *need* Format' appearing on the Student's 2 pre-map of Group 7 (see on the left side of Figure 1) is a false belief since one type of magnetical storage units, i.e. the tape, does not need format.
- *Complete & Accurate Belief (CAB)* is used for scientific beliefs. For example the proposition 'Secondary storage units *permanenlty store* Data' appearing on the Student's 2 pre-map of Group 7 (see on the right top side of Figure 1) is a complete and accurate belief.
- *Partial Accurate Belief (PAB)* is used for toward-scientific beliefs (beliefs that could not be characterized as FB or CAB), i.e. the proposition depicted on the map is correct but a more appropriate relationship between the concepts was expected or the concept(s) of the proposition is(are) not placed at the correct level/position on the map. For example the proposition 'Optical storage units *have lower than main memory* data access speed' appearing on the Student's 2 pre-map of Group 7 (see in the middle of Figure 1) is a Partial Accurate Belief since, although it is correct, this is a characteristic of all the secondary storage units not just the optical ones.

After assessing all the maps collected, the different types of propositions (CAB, PAB, FB) on each map were summed up in order to evaluate individual background knowledge, group and individual outcome. For example, the total number of (CAB, PAB, FB) propositions of a pre-map is considered as the background knowledge of a student or the total number of (CAB, PAB, FB) propositions of a group-map is considered as the group outcome.

Then, the maps were compared in order to identify similarities and differences among students' pre and post-maps and between both (pre and post) CMs with the group CM. In this process, similarities and differences that reflect specific influences between individuals and groups were identified and characterised accordingly [9]. For example, as illustrated in Figure 1, each proposition of the pre-map is characterized as *In-Gr* or *Not-in-Gr* and *In-Post* or *Not-in Post*, depending on its appearance on the group CM and on the post CM correspondingly. Also, those propositions of the pre-map that appear in a different form on the group CM and/or the post-map of the individual, they are accordingly annotated to reflect the type of change, e.g. *Ch-in-Gr-A-CAB* means that the specific proposition has changed on the group CM (i.e. the level of the concepts has changed) and has been evaluated as CAB. Also in Figure 2, a post-map is illustrated where each proposition is characterized as CAB, PAB or FB. Depending on the appearance of the same proposition on the group CM and on the pre CM, the proposition on the post-map is characterized as *In-Gr* and *In-Pre* correspondingly. A proposition of the post-map is characterized as *Ins-Gr*, if it firstly appeared on the group CM reflecting an influence of the group to the post-map and as *I-Pers*, if it appears also on the pre-map of the individual but not on the Group map.

In a later step, we focused on isolating (a) influences of the individuals on the group product by comparing the pre-map of each student with their group-map, and (b) influences of the group on the individuals' products by comparing the pre with the post-maps of each student. For example, the proposition 'Data *sorted in* Files' is characterised as 'In-Gr' on the Student's 2 pre-map since it appears also on the group map (compare Figure 1 with Figure 3) and it is considered as an influence of the individual to the group map. Also, the proposition 'Optical Storage Units *allows data access* Randomly' is characterised as 'Ins-Gr' on the Student's 2 post-map since it appears for the first time on the group map (compare Figures 1, 2 with Figure 3) and it is considered as an influence of the group to the individual student.

In this paper we focus on factors that reflect style characteristics and performance at individual and group level in order to quantitatively estimate dependences among them. In particular, we consider:

- *Individual background:* students' knowledge before collaboration is assessed based on the pre collaboration individual product i.e. the pre-map constructed before the collaborative session.

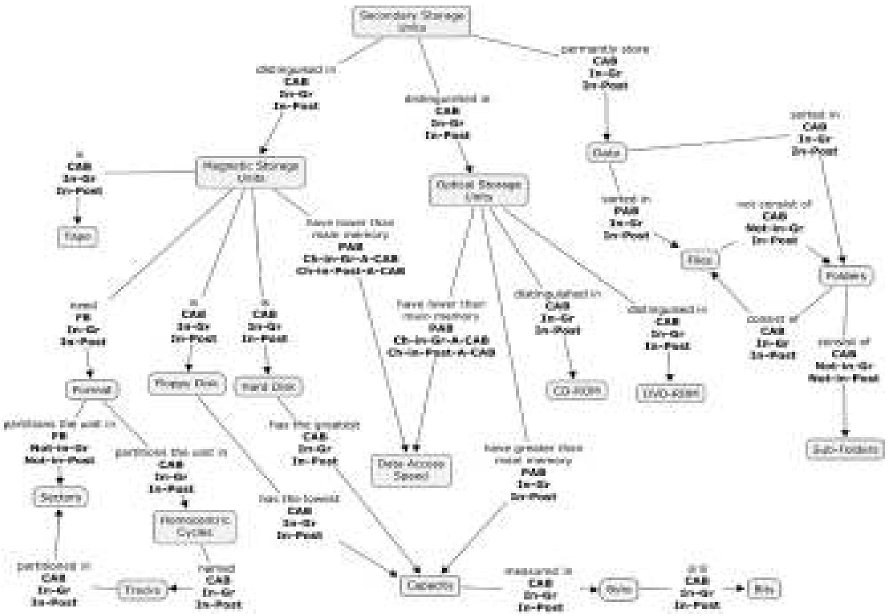

Figure 1. The pre-map of Student 2 of Group 7

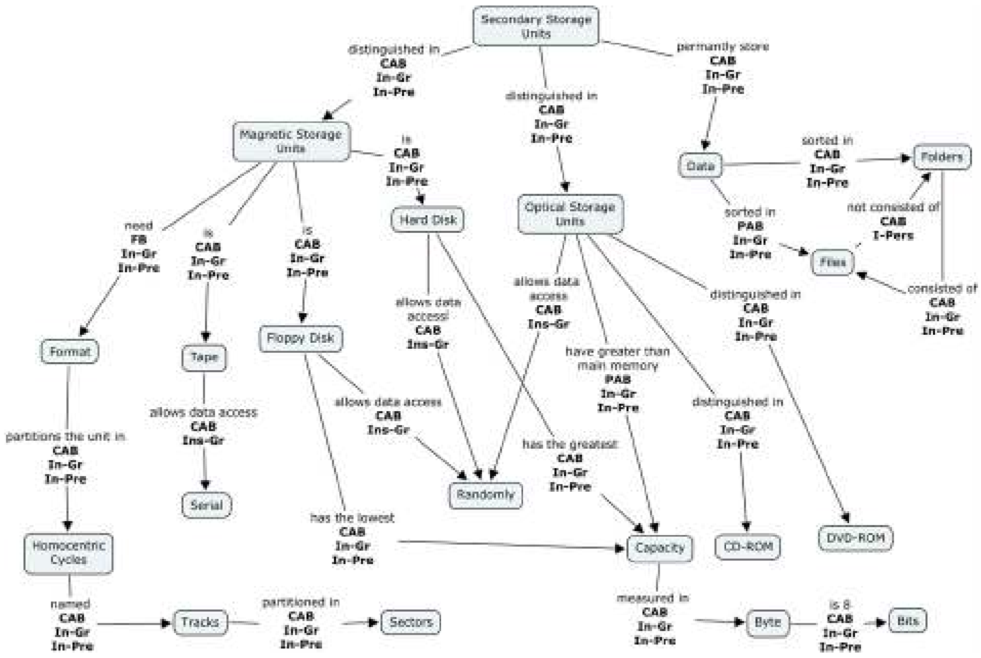

Figure 2. The post-map of Student 2 of Group 7.

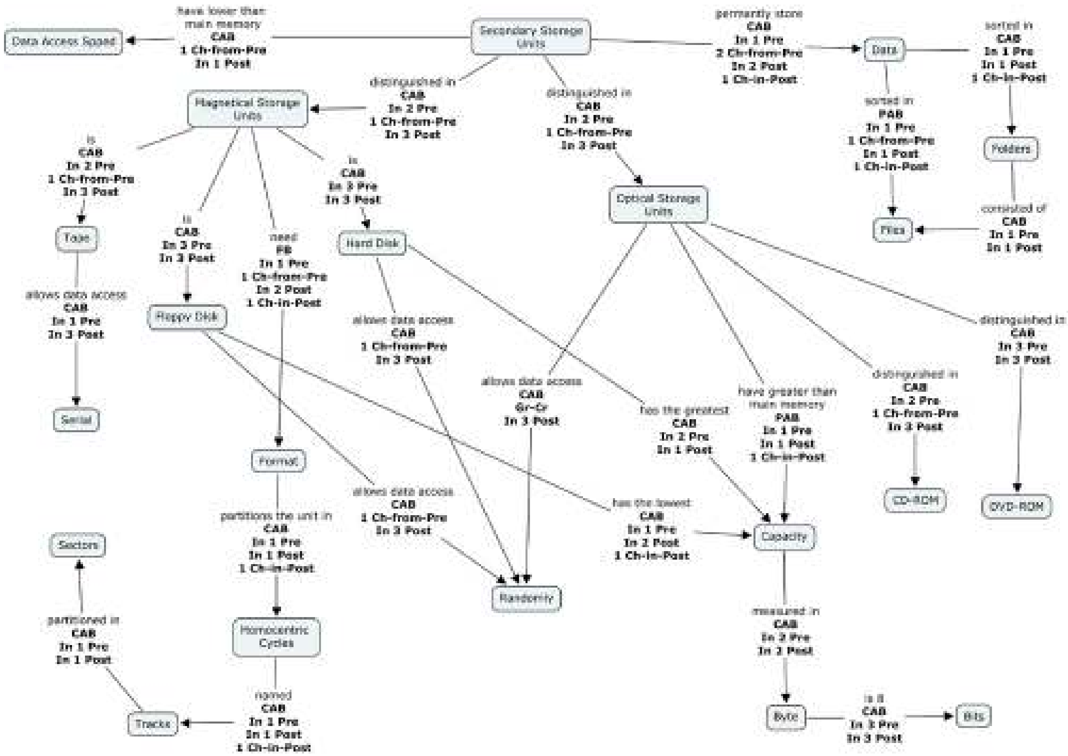

Figure 3. The map constructed by Group 7

- *Individual style*: students' learning style is estimated based on the H&M categorisation. Students' style is characterised based on their stronger preferences.
- *Individual outcome*: students' knowledge after collaboration is assessed based on the post individual product i.e. the post-map constructed after the collaborative session.
- *Individual-to-Group impact (In-Gr)*: the impact that each individual member of the group may have on the group product is estimated by the total number of propositions that s/he managed to transfer on the group product.
- *Group outcome: group knowledge* is assessed based on the group product i.e. the group CM constructed during the collaborative session.
- *Group style*: synthesis of individuals' styles *as a measure of* individuals' influence on the group as an entity.

Individual background, *Individual outcome* and *Group outcome* are estimated by summing up the CAB, PAB, and FB propositions of individuals' pre, post and group maps appropriately weighted. For example, assessing the propositions of the student Std7.2 that appear on her pre-map, her individual background is evaluated as 19 CAB, 4 PAB and 2 FB propositions (see Table II), i.e. her background is calculated by the form 19*3+4*1+2*(-1) = 59. *Individual-to-Group impact* is assessed by the number of (FB, CAB, PAB) propositions of the individual's pre-map that were also transferred in the group map, i.e. they appear in both maps. In our case the *Individual-to-group impact* factor is considered as an impact of individual to group work whilst the *Individual outcome* as an impact of group work to the individual.

C. Results

How individual background affects students' contribution to the group outcome and individual progress in a collaborative session?

Estimating *students' background* (complete and accurate beliefs (CAB) and total beliefs) in relation to the students' contribution to the group map (In-Gr/Group Outcome for CAB and total beliefs), a significant positive relationship between these two variables results for CAB (r=0.75, p<0.01) and total beliefs respectively (r=0.5, p<0.03). It seems that students' background knowledge positively influence their contribution to the group product during the collaboration process. However, the contribution of each student to the group map shows no significant difference in favor of the group style (i.e. homogeneous and heterogeneous).

Moreover, the examination of students' background in relation to their progress from the pre- to the post-map results to a significant negative relationship (r=-0.477, p=0.04). It seems that students with higher background knowledge level had lower progress in their post-individual concept map, while students with lower background knowledge had higher progress.

TABLE II. QUANTITATIVE MEASURES OF STUDENTS KNOWLEDGE BEFORE AND AFTER COLLABORATION

Groups	***Students***	***Individual Background***			***Individual outcome***		
		CAB	**PAB**	**FB**	**CAB**	**PAB**	**FB**
Group1	Std1.1	27	0	6	22	3	6
	Std1.2	15	2	2	23	3	3
	Std1.3	20	2	9	19	1	2
Group2	Std2.1	12	0	6	16	0	3
	Std2.2	16	0	2	17	0	2
Group3	Std3.1	15	0	8	13	1	3
	Std3.2	17	2	6	21	2	4
Group4	Std4.1	31	1	6	29	2	6
	Std4.2	16	0	11	19	1	4
	Std4.3	19	2	4	26	1	3
Group5	Std5.1	27	0	3	26	0	4
	Std5.2	19	1	5	22	1	2
	Std5.3	28	0	2	25	0	4
Group6	Std6.1	24	3	0	29	1	1
	Std6.2	19	1	4	21	2	2
	Std6.3	22	2	2	32	1	1
Group7	Std7.1	16	9	9	16	5	4
	Std7.2	19	4	2	22	2	1
	Std7.3	14	0	5	17	1	4
Group8	Std8.1	18	3	9	22	4	3
	Std8.2	20	3	4	26	1	2
	Std8.3	3	1	4	16	0	1
Group9	Std9.1	16	5	6	21	3	3
	Std9.2	9	9	5	14	3	2
	Std9.3	5	6	7	16	4	5
Group10	Std10.1	14	1	10	10	12	5
	Std10.2	13	3	4	11	7	4
	Std10.3	13	7	5	13	4	4
Group11	Std11.1	18	0	2	16	2	3
	Std11.2	14	0	8	16	0	5
	Std11.3	9	3	2	15	0	4
Group12	Std12.1	16	3	0	21	2	0
	Std12.2	20	4	1	24	1	1
	Std12.3	19	0	4	29	3	0

How group synthesis based on style may affect individual progress?

The two-way mixed analysis of variance (ANOVA) with time (individual background vs. individual outcome) as a within-subjects factor and group style (heterogeneous groups vs. homogeneous groups) as a between-subjects factor was used to analyse the main effect of group synthesis on students' performance. The interaction between the group synthesis and time shows no significant difference ($F_{1,32}$= 0.07, p=0.793). The difference on background knowledge before the collaboration (M_{hete}=54.65, SD_{hete}=20.5, M_{homo}=43.18, SD_{homo}=13.9) and on individual outcome after the collaboration (M_{hete}=64.94, SD_{hete}=15.21, M_{homo}=54.65, SD_{homo}=16.61) are near to the significant in favor of the group style (t=1.91, df=32, 2-tailed p=0.065) (t=1.884, df=32, 2-tailed p=0.069) respectively. This means that the average performance of the heterogeneous groups before and after the collaboration is slightly higher than that of the homogeneous groups. Although, the difference on the performance between the two time-conditions for the heterogeneous groups is not significant (t=-1.663, df=32, 2-tailed p=0.106), for the homogeneous groups, the difference on the performance between the two time-conditions was significant (t=-2.182, df=32, p=0.037<0.05). This means that students belonging to homogenous groups increased their progress more than those belonging to heterogenous groups.

IV. IMPLEMENTATION PARADIGM: THE LEARNER & GROUP MODEL OF COMPASS

Information about how a learner interacts with peers as a member of a group (influences and influenced by the group work) is a valuable resource also for learner and group modeling. This information could be exploited to inform the learner and group models in a collaborative learning context reflecting characteristics of the individuals forming a group, of the group as an entity as well as of group interaction during a collaborative task.

In this context and having as an objective to extend COMPASS with capabilities for supporting collaborative concept mapping tasks, the learner and the group models of the environment will be further developed aiming to enhance feedback provision and reflection at individual and group level.

COMPASS (http://hermes.di.uoa.gr/compass) is a discipline-independent adaptive concept mapping learning environment, developed at the Educational & Language Technology Laboratory of the Department of Informatics & Telecommunications at the University of Athens [4]. COMPASS (i) allows students to work out various concept mapping activities, which employ different concept mapping tasks, (ii) analyses students' maps and provides qualitative and quantitative estimations of their knowledge based on a particular assessment scheme, (iii) provides multiple forms of feedback (text-, graphical- and dialogue-based) and feedback components, which serve processes of informing, guiding/tutoring, and reflection, (iv) adapts the feedback process accommodating students' knowledge level, preferences, and interaction behaviour, (v) promotes learner control over the feedback process, and (vi) supports teachers-experts through the CAT tool (COMPASS Authoring Tool), which enables the design/authoring of concept mapping activities and feedback components, the definition/configuration of the assessment scheme applied and the monitoring of students' progress.

The learner model of the environment currently stores specific characteristics of the learner such as learner's knowledge level, his/her preferences on feedback forms and components, etc. It is used as the main source of the adaptive behaviour of COMPASS and is dynamically updated during learner's interaction with COMPASS in order to keep track of learner's "current state".

Based on the results of the current study, we intend to extend the learner model with information about the state of the individuals before, during and after a collaborative session in order to support learners in collaborative concept mapping tasks. To this end, the learner model has been redesigned and structured in three layers:

- the first layer, named '*Personal characteristics*', includes the initial (before collaboration) learner characteristics as these are evaluated through appropriate questionnaires, tasks, tests, etc. Currently, the learner model keeps: (i) general information about the learner such as username, profession, style, learner's favourite feedback forms and components, last time/date the learner logged on/off, (ii) information about learner's knowledge level (qualitative and quantitative estimation) with respect to the assessment goals/activities that s/he has worked out, (iii) information about learner's errors identified on his/her map, and (iv) information about learner's behaviour during his/her interaction with the environment in terms of the number of times that feedback was asked, feedback components proposed/selected, error frequency, time of response, etc.,
- the second layer, named '*Social characteristics (related or inspired by group work)*' includes learner characteristics derived by learner's interaction with the group through collaboration, such as the factors 'Individual-to-Group impact' and 'Group-to-Individual impact' (e.g. propositions characterized as Not-in-Gr, Not-in-Post and Ch-in-Post),
- the third layer of the learner model, named '*Post-group characteristics*', includes those characteristics identified through the post collaboration individual work of the learner reflecting influences of the group work on the individual, such as factors concerning individual creativity and individual persistence.

A group model will be also designed aiming to depict the state of the group as an entity before and during collaboration as well as its achievement after collaboration. The group model will contain group characteristics, such as group synthesis, influences from the individuals to group work, group creativity, group outcome. Opening such information to the members of a group we intend to enhance participation, group awareness, and promote group work.

V. CONCLUSIONS

The work presented in this paper explores influences of individuals to group as well as impacts of group work to individual progress. An empirical study was conducted in which several factors that account for transfer of learning between groups and individuals through a sequence of individual and collaborative learning tasks were identified. These factors are closely related to particular individual and group characteristics that reflect personal and social characteristics of the individuals that form a group and the group as an entity, as well as features of the group interaction during collaborative tasks.

In this study we adopted an assessment scheme for concept maps based on the relational assessment method aiming to quantify the procedure and estimate individual and group characteristics such as background knowledge, individual and group outcomes as well as dependences among them. Influences among the various student products, inidvidual and group, in the form of similarities and differences, were used as indicators of the impact an individual may have on the group outcome (e.g. In-Gr) and the group on individual progress (e.g. Ins-Gr). Individual and group style characteristics were also considered. Among the findings of this study, in which students worked out concept maps in a I-G-I mode (Individually, Collaboratively, Individually), the following dependences were identified: (*i*) students' background knowledge positively influence their contribution to the group product during collaboration, (*ii*) the contribution of each student to the group product seems not to be influenced by the style of his/her group (i.e. homogeneous and heterogeneous), (*iii*) the student's level of background knowledge relates to the progress of the student in a collaborative session, since students with lower background knowledge seem to benefit more from collaboration in terms of individual progress, (*iv*) collaboration benefit more students working in homogeneous groups.

In our future plans is to investigate how learner and group models extended with the above information may be exploited to (a) support collaboration (e.g. promote student participation in case of a student with high background knowledge and low influence on the group product), (b) extend personalised support functionality and open learner modeling at group level (e.g. support students in adopting CAB beliefs of the group map or acknowledging their CAB beliefs that they rejected on their post-maps, increase 'group awareness'), (c) enhance feedback provision and reflection (e.g. inform learners or groups about their evolution through the work).

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