Concept Mapping as a Medium of Shared Cognition in Computer-Supported Collaborative Problem Solving

NELI STOYANOVA AND PIET KOMMERS

University of Twente
Faculty of Educational Science and Technology
Division of Educational Instrumentation
The Netherlands
P.A.M.Kommers@edte.utwente.nl

This article presents an experimental study aimed at investigating the learning effectiveness of concept mapping for computer-supported collaborative problem solving. The main assumption underlying this research is that shared cognition is substantial for cognitive construction and reconstruction and that concept mapping is an effective tool for mediating computer-supported collaboration.

Three scenarios for “mediated group interaction” by concept mapping have been designed—distributed, moderated, and shared. They are based on the assumption that the form in which knowledge is shared strongly influences the process of shaping, and shared cognition subsequently influences the effectiveness of collaborative learning. These three scenarios demonstrated differential effects towards various aspects of learning effectiveness both at the group and at the individual level. It is concluded that both the mode of sharing and the representation of knowledge as expressed by students are more important than the access to the distributed resources itself. The sharing scenarios showed to be most appropriate for establishing a supportive learning environment.
THEORETICAL BACKGROUND AND RESEARCH RATIONAL

Different theoretical precursors emphasise collaboration as a successful and powerful activity for learning and problem solving. During collaboration students discover, construct, and become aware of their own cognitive structures by representing and explaining their concepts and ideas. Collaboration presents divergent ways of thinking and prompts new perspectives to the problem. It facilitates more flexible cognitive patterns and stimulates critical and creative thinking.

Two concepts and research paradigms are closely related to the problem area of collaborative learning—distributed cognition and shared cognition. In the following section a distinction between the two is made although some researchers use them interchangeably. On that basis the main focus of the experimental research is defined.

Distributed cognition is defined as an extension of the internal cognition of the personality in the outside world (artefacts and other people). It creates a “person-plus” cognition (Perkins, 1993). Teams manifest distributed cognition through a variety of representations and through accessing knowledge ingredients of the group partners (Hutchins, 1991). While exploring the theoretical construct of distributed cognition it could be assumed that in any form of collaboration the personal cognition of the students is constructed by reflection, absorption, and by interpretation of others’ knowledge. For each student in a group, the presentation of the others is a distributed information resource enabling the construction and reconstruction his/her own cognition. The question is not so much whether the cognition of the individual student is distributed, but how the communicated knowledge is integrated in the collaborative process and if it is assimilated in the more personal cognitive constructs. In total: It is a question of, if and how the shared constructs are accommodated and reconstructed during a group collaboration process.

The concept Shared cognition emphasises the mutual understanding of collaborators’ perspectives and shared interpretations of the problem as an essential requirement of collaboration. It is very important that cooperating subjects acquire a common frame of reference to communicate their individual viewpoints. Only knowledge that is meaningful for individuals is internalised and integrated in one’s cognitive structure. According to Salomon (2000) one of the main distinctions between information and knowledge is that while information is discrete, knowledge is arranged in networks with meaningful connections between nodes. While information can be transmitted as it is, knowledge needs to be constructed as a web of
meaningful connections. Information is relatively context independent; knowledge is always part of a context. As the learning process is focused on knowledge acquisition and reconstruction of individual cognition, students should share not only information but they should also share knowledge.

Shared cognition is built upon the individual inputs in the collaborative process. Representing their cognitive structures and negotiating about the meaning of concepts, individuals reach a common vision on the problem. An essential feature of collaborative learning is the process of interaction between individual cognitions and between individual cognitions and the shared group cognition that Salomon (1993) defined as interdependence. Shared cognition at the same is the way a group contributes to “personal meaning” at the level of individual students. All components of shared cognition are meaningfully integrated in the cognitive structure of the contributing persons; they are interpreted on the same frame of reference. The underlying research is basically focused on two aspects of distributed cognition in collaborative learning:

1. the role of the mediating tools used in collaboration, and
2. the modality in which knowledge is communicated during the interaction process.

The concept of mediation refers to the fact that our relations with the outside world (including other people) are always mediated by signs and artefacts. Mind tools, (alternatively known as cognitive tools; Kommers, Jonassen, & Mayes, 1991) are intended to engage and facilitate cognitive processing. As an exemplar of the broad range of mediating tools, this research is focused on only one specific technique—concept-mapping. It investigates its effectiveness in a collaborative learning.

Concept mapping falls into the large category of Mind tools (Jonassen & Marra, 1994). An important advantage of concept mapping is that it models the way the human mind organizes knowledge. Concept mapping offers a close correspondence between psychological constructs and their external mode of representations.

- It uses a simple formal convention—nodes, links and labels on the links.
- It integrates two kinds of coding—verbal and visual.
- It externalises both cognitive and affective processes.
- It stimulates self-appraisal and self-reflection and supports mental imagery (Stoyanov & Kommers, 1999).
Some features of concept mapping promote the assumption that it should be an effective technique for collaboration (Stoyanova, 2000).

- Concept mapping is a unique technique for externalising the cognitive structure of the students. While using concept mapping students communicate based upon the whole picture of the problem space; it represents their prior knowledge and vision. Elaborations of the various perspectives based on concept mapping are much more comprehensive.

- Meanings of the concepts and ideas are clearly defined by the position of the concept in the whole picture and its interrelations with other concepts. This facilitates negotiation of meaning and promotes a deeper mutual understanding between collaborators. It is supposed that the process of group negotiation should trigger internal negotiations at the students and the meaningful integration of the new concepts in the cognitive structure of learners.

- While interacting by concept mapping, students have the possibilities to take a look at the whole problem space as visualised by other group members. It should enhance the process of critical reflection as well as creative thinking.

The second point of our interest is the mode of collaborative interaction defined by the specific form in which the knowledge is involved in collaboration. According to Hedlund and Nonaka (1994) knowledge exists in three forms:

1. as individual mental constructs and precepts,
2. as knowledge in action, and
3. as knowledge embodied in artefacts.

The distributed cognition of a person is based on sharing and exchanging externalised knowledge (artefacts). Students undertake their individual learning actions towards these artefacts, interpreting them according to their own frame of reference and internalising all or a part of them in one’s own cognitive structure.

Activity theory (Vygotsky, 1986; Leont’ev, 1978; Kuutti, 1991; Jonassen, 2000) characterises learning as a process of appropriation of the sociocultural meaning externalised in artefacts. Learning is based on the adequate socially determined activity of a subject towards an object in which the knowledge is internalised in a meaningful way.

Sharing “knowledge in action,” means “sharing externalised knowledge,” but also “sharing activities against knowledge,” thus “sharing the
process of learning itself.” Shared meaning is generated through exchange (Pea, 1993). It is a reliable base for developing a shared cognition.

The following sections present the design and the main results of an experimental study aimed at investigating the learning effectiveness of concept mapping as a mediating tool of collaboration under different conditions of group interaction.

EXPERIMENTAL VALIDATION

To investigate the learning effectiveness of concept mapping in a computer-supported, collaborative, problem-solving environment and how this effectiveness depends on the mode of group interaction an experimental study was undertaken. The main assumption underlying this research is that shared cognition in collaborative learning is substantial for cognitive construction and reconstruction and that concept mapping is an effective tool for mediating shared cognition.

Collaborative Scenarios

Based on the assumption that the form in which knowledge is shared influences strongly the process of building a shared cognition. Three scenarios of concept mapping-mediated group interaction have been designed:

- **Distributed interaction.** Group members work autonomously and produce intermediate artefacts (maps) embodying their knowledge and visions that are passed to the other members. This action is repeated until all group members reach a common vision of the problem. The process of knowledge acquisition, creation, and internalisation is individual.

- **Moderated interaction.** The interaction process is facilitated by a group moderator (the role is taken by one of the group members) who adjusts the individually produced artefacts until a common group vision is reached. The representations of individual cognitive structures are not directly accessible but group members are involved in the process of negotiation on meaning and connotations that take place between them and the group moderator.

- **Shared interaction.** Group members interact directly by synchronous activity and common efforts to solve the problem as a group. They share their knowledge in action. Knowledge is communicated in the process
of its appropriation and creation. Collaborative actions of students are the individual inputs toward shared cognition.

In summary, the main assumption is that the effectiveness of learning (both as a group and an individual) significantly depends on the mode of mapping-mediated group interaction. The three modes previously described affect in a different way, both the group and the individual learning effectiveness. Focusing on the higher-order learning in an ill-structured problem situation, the sharing mode should be the most appropriate for establishing a supportive learning environment for problem-solving. It enables the full potential of the concept mapping method.

Subjects

Twenty-six students (6 groups) from the University of Twente, the Faculty of Educational Science and Technology, enrolled in the Linear and Hypermedia course. They were selected as experimental subjects and were randomly assigned to four types of problem solving treatments (mapping versus control). The groups were distributed as follows:

- distributed mapping mode—2 groups;
- moderated mapping mode – 1 group;
- shared mapping mode—2 groups; and
- the Control Group did not use the mapping mode—1 group. The control group was instructed to use Brainstorming method for their collaboration.

Procedure

The experiment took place during the design phase of the Linear and Hypermedia course. This course was project-based, problem-solving oriented, and student-centered. Students who enrolled in the course had to design and develop a multimedia (hypermedia) product on the topic Cheese and cheese production. During the first panel session of the course students were introduced briefly to the concept mapping technique with the Inspiration concept mapping software.

The experimental procedure consisted of three main parts:

1. **Pretest.** Before the experimental session a pretest was conducted as an individual task. Students were asked to make a paper and pencil concept
map representing their personal knowledge, vision, and understanding of the task. Before the collaborative experimental session all pretest concept maps were collected.

2. **Collaborative experimental session.** Students were assigned to the groups and received written instructions on how to proceed with their group work. The task of the collaborative session was to reach a common group vision (represented in map format for mapping groups and in an outline format for the control group) about the conceptual structure of the topic based on their prior knowledge and personal visions. Students were not advised to search additional learning resources. The group outputs were collected. The sessions were audio- and videotaped.

3. **Posttest.** To capture the individual learning outputs after the group work the same task as in the pretest was proposed to the students a week after the experiment session. They were asked to make a concept map on the topic as an individual task.

**Experimental Design**

The experimental design is a randomly assigned pretest posttest control group. It reflects two specific features of group learning in an ill-structured problem situation.

Both the pretest and posttest are not considered an achievement test. As far as an ill-structured problem situation is concerned, no unconditional right solution of the problem could be used as a criterion for successful group collaboration or an individual learning. The pretest and the posttest were aimed at capturing the actual state of students’ cognitive structure about the problem.

The second concern was to escape from the so-called “group attribution error” (Allison & Messick, 1987). This phenomenon called also “correspondent influence bias” (Gilbert & Jones, 1986). It refers to the people’s tendency to assume a direct correspondence between a group decision, choice, or evaluation, and the visions and performance of the members of the group.

The operationalization of the experimental variables reflect the understanding of the group as an integral whole that could not be presented just as a sum of individual inputs and of the individual cognition as influenced by the group process but not just a reflection of the group vision. Learning effectiveness is defined as individual learning effectiveness, as effectiveness of the group output, and as individual-group transfer effectiveness.
The experimental design is presented in the Venn diagram (Figure 1), where $S_1$ – $S_n$ are individual students. On the base of this model the dependent variable is operationalised and coded.

![Figure 1. The model of the experimental design](image)

The independent variables are:

- The mediating tool for collaboration with two levels—concept mapping and the traditional no mapping approach.
- The mode of group interaction with three levels—Distributed, Moderated, and Shared.

The dependent variable is the learning effectiveness of collaborative problem solving operationalised in three dimensions as follows:

1. Learning effectiveness at the level of individual students, scored numerically on posttest concept mapping production in terms of:

- **Fluency.** Fluency is defined as the total number of concepts representing one’s individual understanding of the problem. The total number of nodes in an individual posttest concept map measures it. Concept fluency is representative for the richness and broadness of the understanding of the students about the problem after the collaborative session (Figure 2).

![Figure 2. Fluency](image)
Cognitive Mapping as a Medium of Shared Cognition

• **Flexibility.** Flexibility represents the distribution of concepts on different levels in relation to the central concept. Conceptual levels are defined by the shortest link to the central concept. Respectively the concepts that are directly linked to the central concept are at Level 1; these that are related to the central concept through one mediating node are at Level 2; concepts mediated to the central concept by four or more nodes are on Level 5. It is assumed that closer the concepts to the central node greater their importance for defining and understanding the problem (Figure 3).

![Figure 3. Flexibility](image)

Knowledge acquisition is indicative for the number of the acquired new concepts by a student. It is measured by the number of the concepts in a posttest that could not be found in the same student’s pretest. This category is representative for the concepts learned during or because of the collaboration (Figure 4).

![Figure 4. Knowledge acquisition](image)

• **Retention.** Retention is indicated by the number of concepts in the individual pretest that are transferred to the same person’s posttest. This category is indicative for the knowledge in the personal cognition that is
stable, as well as for the personal intellectual autonomy in the process of collaboration (Figure 5).

**Figure 5. Retention**

- **Individual creativity.** Individual creativity is indicative for the new concepts and ideas generated individually after the collaboration. It is measured by the number of the nodes in the posttest that could be found neither in the same person’s pretest nor in the group map. The underlying assumption is that presentation of different perspectives on the problem in the collaboration is a stimulus for individual creation of new ideas and visions (Figure 6).

**Figure 6. Individual creativity**

- **Reconfiguration.** Reconfiguration is defined as the changes in the concepts’ structure. It is represented by the movements of the concepts between levels, by (re-) grouping and (re-) clustering of the nodes, as well as by the reshaping of map spatial configuration.
2. Learning effectiveness at the level of the group as a whole, scored numerically on group concept mapping production in terms of:

- **Fluency.** The total number of concepts in the group problem solution measures group fluency (Figure 7).

![Figure 7. Fluency](image)

- **Flexibility.** Similar to the individual map fluency, group map fluency is measured by the distribution of concepts on different concept levels in relation to the central concept.

- **Retention.** Retention is counter indicated by the number of concepts in the group map that are not transferred to one of the individual posttest representation (Figure 8).

![Figure 8. Retention](image)

- **Group creativity.** New concepts and ideas generated in the collaboration session are measured by the number of concepts in the group problem solution that could not be found in anyone’s pretest. The assumption is that creativity is provoked by the collaboration and could be a shared group phenomenon (Figure 9).
3. Learning effectiveness as an interaction between individual students and group achievements, scored numerically on both individual and group input and outputs in terms of:

- **Individual-to-group transfer.** Individual-to-group transfer is indicative for the individuals’ inputs in the group solution. It is measured by the number of concepts in the group solution that are derived from (exist in) at least one of the group member’s pretest (Figure 10).

- **Group-to-individual transfer.** Group-to-individual transfer represents the knowledge that is transferred from the shared group cognition to the individual cognition and is indicative for the individual learning output. It
is measured by the number of the concepts in the group solution that could be found at least in one group member’s posttest (Figure 11).

Figure 11. Group-to-individual transfer

Data was analysed applying one-way ANOVA and a covariation procedure by the SPSS 9.0 Statistical Package. To define the specific differences between groups a Bonferroni posthoc test of multiple comparison was conducted.

RESULTS AND ANALYSIS

In the following section, the main experimental results are presented. They are analyzed and discussed around the two main focuses of the presented research: the role of concept mapping as a mediating tool of collaboration and the effect of mode of group interaction.

Concept Mapping as a Mediating Tool for Sharing Cognition

The first research question addressed here is what is the learning effectiveness of concept mapping in a collaborative problem-solving environment. The experimental data are presented and analyzed according the research model and operationalization of the concept of learning effectiveness.

Individual learning effectiveness. The results indicative for the learning effectiveness are presented in the following space according to the operationalization scheme.
**Fluency and flexibility.** A comparison between groups that have used mapping techniques and the control group that has used brainstorming techniques revealed that concept-mapping techniques strongly influence the conceptual fluency as a parameter of the individual learning effectiveness ($M_{map} = 26.41; M_{contr.} = 8.00; F = 7.395, p = .014$). Students in concept mapping groups showed better results in their posttest as a total number of concepts covered in the problem space than students in the control group (Figure 12).

![Figure 12. Effect of concept mapping on individual fluency and flexibility](image)

The distribution across concept levels shows a difference that is significant at Level 1 ($M_{map} = 6.47; M_{contr.} = 2.00; F = 4.837, p = .040$), Level 2 ($M_{map} = 13.59; M_{contr.} = 1.80; F = 5.837, p = .026$) and Level 4 ($M_{map} = 0.88; M_{contr.} = 3.51; F = 11.610, p = .003$). Students in the mapping groups tend to construct the problem space in several problem clusters that is shown by the greater number of nodes at Level 1 and to present at Level 2 the most of the concepts. The Levels 3, 4, and 5 show a relatively lower number of concepts. The fact that most concepts are distributed at the Level 2 and Level 1 could be interpreted in terms of concepts’ importance for the problem. It is supposed that the closer a concept is to the central idea the higher are its importance and significance for the understanding and capturing the problem. Students from the control group produce maps with relatively equal distribution of concepts on Levels 1 to 4. Their maps are more linear. It could be concluded that for them it is more difficult to capture and keep in mind the complexity of the problem space.
Enrichment, Knowledge, Acquisition, and Retention

Mapping groups score higher than control groups on enrichment criterion as the difference is near to the significant ($M_{\text{map}} = 12.53; M_{\text{contr.}} = 1.50; F = 3.707, p = .069$). Enrichment is caused by two opposite options: acquiring and incorporating new concepts in the cognitive structure (Knowledge Acquisition) and reduction or exclusion of concepts (Retention).

Using concept mapping is predictive for the new knowledge acquisition and incorporation in the cognitive structure. Mapping students include many more new concepts in their posttest than students in the control groups ($M_{\text{map}} = 15.71; M_{\text{contr.}} = 4.00; F = 4.457, p = .048$).

The process of retention shows no significant difference. The expectation that because of its reconstructive power mapping approach should influence the personal autonomy, and hence the retention process, is not confirmed. A possible explanation is that the use of mapping representation frees some memory space and students do not need to reduce the number of concepts in order to incorporate new ones.

On the criteria of Individual creativity and Reconfiguration no significant difference was found. Our assumption that the use of concept mapping will create opportunities for individual pattern breaking is not confirmed. It should be mentioned here that the results of the control groups that have used brainstorming methods, recognized as highly beneficial for creativity, are compared with the results of all mapping groups using different methods of collaboration.

Learning Effectiveness as an Interaction Between Individual Students and the Group

Probably the most interesting criteria for predictive power of concept mapping for the learning effectiveness in collaborative learning are the interaction between group work and individual cognitive reconstruction:

Individual-to-group transfer shows a difference near to the significant in favor of mapping groups ($M_{\text{map}} = 11.47; M_{\text{contr.}} = 4.50; F = 4.312, p = .052$). Group-to-individual transfer is significantly higher for mapping groups ($M_{\text{map}} = 19.71; M_{\text{contr.}} = 5.50; F = 3.827, p = .047$).

One of the main challenging aspects of collaborative learning is to find an efficient way to elicit individual knowledge in collaborating groups and
to communicate them. According to the results of this study, concept mapping is an effective tool for eliciting, representing and communicating knowledge in collaboration in a way that is meaningful and beneficial for all participants.

It could be summarized that concept mapping as a mediating tool is beneficial for group collaborative learning both at group and at individual level. It promotes establishing a common reference structure that is a basis for building shared group cognition. The use of concept mapping makes individual knowledge more explicit and more meaningful for other group members. It could be easier communicated, reflected and elaborated and then easier incorporated in individual cognition. In collaborative settings concept mapping is predictive for a conceptual change and cognitive reconstruction, for acquiring concepts and incorporating them in the existing cognitive structure as well as for the reconstruction of the cognition.

**The Mode of Group Interaction as a Predictor of Learning Effectiveness**

The second research question the study is attempting to answer is how the mode of group interaction influences the learning effectiveness of collaborative problem-solving. The main findings indicative for the influence of the mode of interaction are presented in the space below.

**Individual learning effectiveness.** In general the experimental results show that the mode of interaction is strongly predictive for the individual learning effectiveness of collaborative problem solving. It reveals the priority of the “Shared” mode of interaction in exploring the problem space.

**Fluency and flexibility.** The mode of group interaction influences significantly the concepts fluency \((F = 3.827, p = .047)\) and links fluency \((F = 3.797, p = .048)\).

The precise distribution of results between groups shows a superiority of “Shared” groups, followed by the “Moderated” groups and the “Distributed” groups. A posthoc analysis by Bonferroni multiple comparisons shows that the difference is significant between “Shared” and “Distributed” groups \((MD = 19.25, p = .046)\) (Figure 13).
The distribution of the nodes across concept levels shows that the main difference is caused by the variance on conceptual level 2 as the difference here is near to the significant ($F = 3.394, p = .063$). This suggests that the broadness of students’ perception is caused not just by extension of the problem presentation beyond the task or by adding details. A possible perspective of interpretation is that the differences in conceptual fluency caused by the mode of group interaction is meaningful as far as they concern mainly the most central aspects of the task. A multiple comparison analysis reveals again that the difference is more significant between Shared and Distributed groups ($MD = 14.00, p = .069$) and the Moderated groups have a middle position.

**Enrichment, Knowledge Acquisition, and Retention**

The conclusion that the “Shared” mode of interaction is the most beneficial is supported also by the data about students’ knowledge enrichment. A comparison between posttest and pretest knowledge shows a marginal significance in the growth of the cognitive picture on the task ($F = 3.126, p = .075$). The difference is more significant between “Sharing” and “Distributing” students ($MD = 14.63, p = .087$) as the “Moderated” students take the middle position.
The mode of group interaction appeared to be strongly beneficial for incorporating new knowledge in the students’ cognition. The difference of acquired new knowledge between groups is significant \((F = 3.905, p = .045)\) showing the superiority of the “Shared” mode against the “Distributed” mode \((MD = 15.63, p = .047)\). Students working in the “Moderated” mode also incorporated fewer new concepts in their personal cognitive structure than students in “Shared” mode. An additional qualitative analysis shows that only those aspects of the group solution that were developed by the personal participation of a particular student were internalised in his/her cognition. Students in the “Distributed” mode had a broad access to all other students’ knowledge representation. However they were not able to gain from others’ experience as much as the students in “Moderated” mode.

A possible explanation is that the “Shared” mode of interaction supports a deep understanding of knowledge. The “Shared” collaboration benefits because it is based on knowledge in action rather than because it provides a direct access to all group members’ representations. It leads to making the articulated concepts meaningful for all collaborators. It is a prerequisite for the incorporation of new concepts in the existing cognitive structure. It could be concluded that the mode of sharing and the form of knowledge, which students communicate are more important than the access to the distributed resources itself. The process of retention shows no significant difference, although it should be mentioned that students in “Distributed” mode reduced fewer concepts from their initial vision of the problem.

For the criterion of formal reconfiguration (movement of the concepts between levels) no significant difference was found. An analysis of the maps reveals that both the “Shared” and “Moderated” modes proved their potential for reconstruction of the individual cognition represented mainly by reshaping of map spatial configuration. Interdependence between spatial configuration of the common group problem solution and the individual outputs is found. The most of the students working within “Distributed” mode do not change their prior map spatial configuration.

Surprisingly, the individual creativity is not influenced by the mode of group interaction. No significant difference was found. A possible reason could be that collaboration triggers the creative process mainly during the group interaction. Group creativity that is going to be discussed later shows significant difference between the three modes of interaction. However a long-term inspiration effect was not observed.
Group Effectiveness

The analysis of group learning effectiveness as expected shows a superiority of the Shared mode of interaction on the criteria of concepts and links fluency as well as on the criterion of group creativity.

Fluency and Flexibility

As expected, the data indicated a great difference in the acquired knowledge especially between “Shared” and the other two types of groups. The broadness of the group vision about the problem is strongly influenced by the mode of interaction.

Surprisingly the “Moderated” groups score higher on criterion of concept fluency than the “Distributed” groups. It was assumed that the opportunity to review all members’ individual maps as an access to considerable amount of distributed cognitive resources should positively influence the broadness of group problem solution. In fact, the way and the form in which individual cognitive resources are represented and manipulated in the group interaction is a stronger factor of group learning effectiveness than the amount of distributed resources to which students have an access and how direct this access is (Figure 14).

![Figure 14. Examples of group concept maps](image-url)
Creativity

The superiority that the “Sharing” mode shows on this criterion should be expected; moreover it is based on some features of brainstorming method that has proved its creative power. Comparing the results on criteria of fluency and creativity it becomes clear that the main source of the differences between group results is the ideas generating process during the group session rather than the incorporation of the group members’ prior knowledge.

Learning Effectiveness as an Interaction Between Individual Students and the Group

The data analysis shows that the mode of interaction itself does not influence the process of eliciting individual knowledge in group collaboration and their incorporation in the group final output. No significant difference was found on the criterion of individual-to-group transfer. All three scenarios enabled students to present and incorporate their knowledge in the group process.

On criterion of group to individual transfer a strong significant difference was found ($F = 13.843, p = .000$) On this criterion students in “Shared” groups score significantly higher than students both in “Moderated” ($MD = 9.35, p = .010$) and “Distributed” ($MD = 14.00, p = .001$) groups. A significant number of the knowledge that is elaborated in the “Shared” session is incorporated as a meaningful part of students’ cognitive structures and is transferred to individual cognitions.

When comparing the predictive power of the mode of interaction for the group learning effectiveness and the individual learning effectiveness, it is obvious that the “Sharing” mode is the most beneficial for both of them. It could be expected that there is interdependence between group and individual learning effectiveness and that the more successful groups are more beneficial to their members as individuals.

Distributed Cognition Redefined

The initial conceptualisation of Distributed Cognition was an extension of the internal cognition of the personality in the outside world; both
Cognitive Mapping as a Medium of Shared Cognition

artefacts and other persons. To clarify this rather formalistic definition an adjacent connotation was chosen and implemented in the experimental conditions: Shared Cognition. To make “shared cognition” operational, the commodity of concept mapping was introduced. The key question was to what extent the process of shared cognition, showed similarity or even superiority to the condition of distributed cognition. The attribute “shared” was defined as “synchronous” and “all members involved in the same collective need for a solution.” The results, after screening the group interaction process and the solution as outcome, was that the shared condition provoked a more intense collaboration and that it revealed a more dense conceptual representation of the problem space. This brings us back to the key element in the more global characteristic of “distributed cognition”. It appears that the fact of sharing knowledge is a prerequisite but not necessarily optimal; the rhythm and the reality binding (feeling mutual needs for arriving at a solution) is a critical factor that can be attained through the process of “sharing.” In conclusion we plead for a closer interpretation of the key underlying mechanism in distributed cognition. Just as the process “conversation” differentiated into a wide variety of “mutual discourses” such as the Platonic dialogue, we may also expect that distributed cognition will undergo evolutions in various directions in the coming years. The direction of “shared” cognition is very promising.

SUMMARY AND FURTHER PERSPECTIVES

In summary, the experiment revealed that the learning effectiveness is significantly influenced by the mode of group interaction. In general, the “Shared” interaction scenario proved to be the most effective in collaborative learning and problem-solving. This leads to the conclusion that learning effectiveness depends on the extent to which students share their learning; not only as results, but also as a process of knowledge acquisition and creation by a direct interaction. Experimentally validated “Shared” interaction scenarios could be implemented in constructing collaborative learning environments. From the perspective of computer-supported collaborative learning, the “Shared” mode has a limitation of being used only in synchronous settings. The next step may be to find precisely which are the most distinctive features of this mode of concept mapping mediated collaboration and how they could be incorporated or/and compensated in the conditions of asynchronous collaboration.
References


