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A review of web-based collaborative learning: factors beyond technology

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Abstract Web-based collaborative learning has a large potential for knowledge acquisition. However, it has different characteristics compared with conventional learning scenarios; especially with respect to the social communication situation, message exchange, cognitive load and participation of the learners. To cope with possible problems resulting from these characteristics suitable instructional means have to be considered, like collaborative learning methods, on-line moderation, appropriate learning tasks or computer-based visualisation tools.

Keywords: Asynchronous; Collaboration; Distance; Learning environments; Mediated; Synchronous; Visualisation; World-wide web.

Introduction

The new learning and communication technologies offer special possibilities, amongst other individualised learning, a broad dispersion of learning offers, an efficient learning administration and above all collaborative learning of locally distributed persons. Collaborative learning involves the joint construction of meaning through interaction with others and can be characterised by a joint commitment to a shared goal (Lewis, 2000; Littlejohn & Häkkinen, 1999). In doing so, learners work together on a topic, exchange their opinions about a subject matter, clarify the meaning of knowledge concepts or aim at a joint problem solution. Each learner taking part in collaborative learning renders activities, like reading, analysing or predicting, which are characteristic for individual learning and which trigger learn-relevant cognitive processes, e.g. induction, deduction, or compilation. However, beyond these activities in the course of collaborative learning, further group-related learning activities result, like explaining, mutual assistance, and mutual regularisation or disagreement, which in turn generate respective cognitive processes, e.g. knowledge elicitation, internalisation, or reduced cognitive load. It is these activities or cognitive processes which have been claimed as favourable for collaborative learning (Dillenbourg, 1999).

It is critical to be aware that there is no guarantee that the desired activities in learning groups actually occur. To ensure collaborative learning a number of instructional supporting measures have been developed to stimulate learning-favourable activities (see Cohen, 1994; Slavin, 1996). These measures have been proven as suitable for face-to-face-situations but have only partially been tested for

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net-based collaborative learning (e.g. Hron *et al*., 2000; Weinberger *et al*., 2002). Net-based communication has some characteristics, which have to be taken into account in order to support collaborative learning. In the following sections specific characteristics are pointed out in conjunction with possible difficulties of communication and learning and suitable instructional measures are discussed.

Specific characteristics of net-based collaborative learning

Social situation

In many cases computer-mediated communication is the only possibility for allowing locally distributed persons or groups to communicate both synchronously and asynchronously. However, this leads to social situations, which deviate from familiar face-to-face situations. Social presence in computer-mediated communication does not exist to the extent that is typical of face-to-face situations, and thus has to be supported by suitable didactical arrangements and instructional measures (Roschelle & Pea, 1999; Swan *et al*., 2000). Depending on the particular communication medium certain kinds of information (mimic, voice, gestures, clothes, etc.) are missing. In text-based asynchronous scenarios there is no possibility to acknowledge understanding by non-verbal and tonal hints. This must be taken into account especially when net-based learning groups have to work on tasks with high communication requirements. Moreover, certain mechanisms are more or less suspended, like the smooth turn taking of speakers and listeners and social interaction rules, according to which at one time only one person speaks and at one time only one topic is treated. There is no smooth, intentional managed turn taking, and as a result topic coherence is at risk (Herring, 1999).

These features also exist in synchronous text chats, at least rudimentarily. Even videoconferencing does not permit social presence as in face-to-face situations (Reiserer *et al*., 2002). Eye contact is not possible among the distant learners, and their focus of attention cannot be understood by view pursuit. References to objects or circumstances are often not clear (O'Conaill & Whittaker, 1997). Suitable instructional supporting measures have to be established in order to alleviate possible problems resulting from these characteristics.

Message exchange

The exchange of messages in net-based learning scenarios offers considerable advantages. In asynchronous communication the permanence of the messages and the temporal flexibility make it possible that reports can be read and answered in peace. Likewise, topics can be discussed temporally in parallel and separated into topics making structured discussions for larger groups possible. A further advantage can arise as a result of the fact that mutual message exchange between participants can take place at any time and so participants do not have to wait for explicit turn taking (Schwan *et al*., 2002). However, involved with these advantages are special features, which make considerable demands on the learners. Net-based learning scenarios cause temporal delays in message exchange, which affect the contextual structure of the exchanged messages. As a result in asynchronous scenarios the consistency of the messages is very variable. A reaction latency of 1.5 days (span from 20 min. to 6 days) on the average has to be taken into account so that communication episodes extend over a longer period (Friedrich *et al*., 2001a). In order to regulate the message exchange, the group members use different

communication strategies. For example, they write longer reports than in face-to-face scenarios, address several topics within a message or discuss several topics in parallel. Thus multiple and interwoven lines of argumentation can result. In addition, the accumulation of exchanged messages can lead to difficulties, because the sheer number of messages may become overwhelming. In synchronous scenarios, e.g. in a text chat, delays can also occur: Writing a message takes time, likewise the reaction to several messages which are received at the same time, or long transmission times, can occur. In videoconferences the latter can cause asynchronous picture and sound transmission and this disturbs the communication (O'Conaill & Whittaker, 1997).

Cognitive load

Although computer-mediated communication offers many advantages, one should not misjudge the fact that net-based collaborative learning makes great demands on its learners, who must operate a complex technology, deal with an often complex subject matter, as well as communicate with other learners at the same time (Sweller *et al*., 1998; Van Bruggen *et al*., 2002). The communication context alone can lead to difficulties, especially if the learners do not have prior experience with communication media. Usually, one cannot assume that all learners posses the necessary computer literacy as a learning prerequisite. Therefore, individual or collective support, or training measures must be planned before or accompanying learning. However, these measures may cause an extra learning effort, which can compete with the actual learning task. A further load in net-based learning can result from the fact that the interaction and collaboration between the group members does not casually occur, but has to be explicitly initiated and maintained by them. Moreover, taking into account the necessary content related engagement and that the exchanged messages often can only be overviewed with difficulties, then it becomes clear that the cognitive load on the learners must be absorbed by supporting measures in order to avoid negative consequences for collaborative learning (Kirschner, 2002).

Participation

In order to reach the goals associated with collaborative learning a critical mass of learners' active participation is necessary (Barab & Duffy, 2000). Learners, as a basic precondition, have to read the messages and ask questions, comments and answers. Actively participating learners realise the entire spectrum of these activities, whereas passively participating learners — so-called lurkers — restrict their activities to reading the messages (Fries, 1995). The high demands on motivation to participate are yet shown by the fact that already passive participation requires a number of media related activities: starting a computer, logging-in into a conference system, selecting a message and reading and understanding it. For active participation still further steps are necessary: producing a written contribution (in text-based communication), inserting it into a topic and comment structure, and addressing it to the desired addressees. Beyond this learners have to decide when and how often they bring themselves into the learning process (e.g. for once a week) and, usually depending on the number of the messages, how long they will take part and which contributions they will read and answer (Schwan *et al*., 2002). Cognitive load and the possible anonymity of communication might result in less motivated learners withdrawing from active participation. Instructional support is essential to alleviate possible communication and learning problems.

Instructional support

Basic instructional preconditions

Firstly, it should be understood that suitable multimedia equipment, communication tools and transmission time are basic prerequisites for providing net-based collaborative learning. Secondly, the curricular integration of the collaborative learning unit is a relevant need in order to support motivation of the learners to participate. In this respect, a suitable preparation and presentation of the subject matter, which has to be meaningful for the learners, is indispensable. Thirdly, measures should be considered, which address extrinsic motivation, like individualised performance records or participation proofs at group works and conferences. Fourthly, appropriate group sizes should be set up to ensure for each group a critical mass of participation, i.e. somewhat larger than conventional learning groups. Fifthly, learners should have access to a substantial information system informing them about special features of net-based communication and learning. As an example, they should be informed that work and learning processes are extended as a consequence of the reaction latency in net-based communication — if not a suitable time schedule will be given as a direct instructional measure (see Harasim *et al*., 1997 and Swan *et al*., 2000 for an extensive discussion of instructional preconditions). Aside from these essential preconditions in the following four important instructional supporting measures are discussed, which seem suitable to cope with possible problems of net-based collaborative learning described above.

Collaborative learning methods

In view of the positive experiences with collaborative learning methods in face-to-face scenarios (Slavin, 1996) it is obvious to use these methods also for net-based learning. These methods structure the interaction and learning processes of the group members and seem therefore to be apt to cope with problems of net-based message exchange and participation. Collaborative learning methods range from global learning methods for organising group work to behaviour rules for structuring dialogues, so called co-operation scripts (Dansereau, 1988; Webb & Palinscar, 1996). Global methods are based mostly on the fact that subgroups work on subtasks, which then enter into a common group work. Examples are role-play, debates or group jigsaws (Paulsen, 1995). Although little is known about the suitability of these methods for net-based learning, more is known about the effectiveness of co-operation scripts. They aim at controlling the dialogue of the group members by given rules mostly to support content related work on the task (Hron *et al*., 2000). These rules can help to regulate the net-based message exchange, e.g. by controlling turn taking or purporting certain reactions or answers of the group members. An example is the semi–structured communication interface of Baker & Lund (1997) shown in Fig. 1, which integrates dialogue rules of a net-based learning scenario. In this scenario two learners design an electrical circuit together by a computer-based graphics editor. For the sake of simplicity the screen area with the graphics editor is omitted here.

As one sees, the communication interface contains predetermined messages for dealing with the task, for mutual agreement, and for co-ordination. By mouse-click the dialogue partners can select the appropriate message from the screen panel. Naturally, such a communication interface avoids problems of message exchange by

purporting a clear dialogue structure that, at the same time, enforces participation of the learners. Baker & Lund (1997) in their learning scenario showed a more deliberated problem solving caused by this interface. Hron *et al*. (1997) implemented similar dialogue control. They found an improvement on discussions with more subject orientated argumentation and better problem solving, but no positive effects on knowledge acquisition. Applying such co-operation scripts, one has to take into account that too much control on dialogue can actually diminish motivation and endanger the autonomy of the learners in mutual knowledge construction. Moreover,

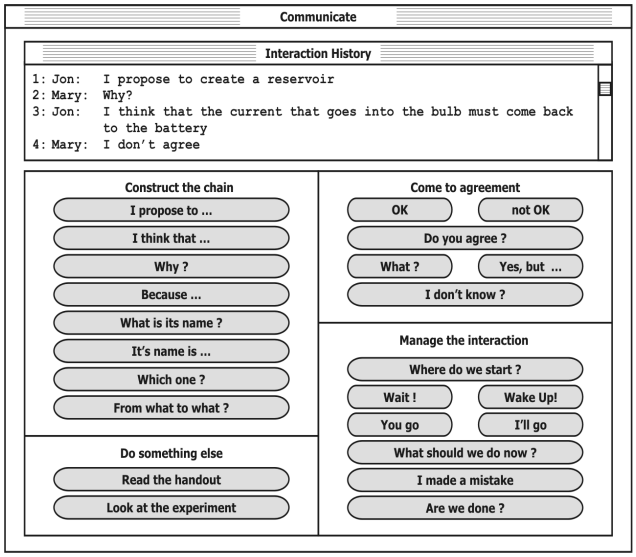

Fig. 1. Communication interface (Baker & Lund, 1997)

such co-operation scripts are not practical for all subject matter domains.

Thus open suggestions for structuring group work are not collaborative learning methods in a genuine sense, however, they are a form of instructional intervention helping the group to cope with difficulties in net-based learning. Examples are suggestions how to define work topics, how to schedule the dates for preliminary reports and deadlines or how to structure the work routine within the group (Dillemans *et al*., 1998). Such structuring suggestions can relieve the cognitive load of the learners and facilitate their participation. However, they are less obligatory and can be accepted by the learning groups more or less at will. Friedrich *et al.* (2001b) gave suggestions to net-based asynchronous learning groups concerning the work routine for a corporately written report following a model of collaborative editing of text documents (Saunders, 1989; see also Erkens *et al*., 2002). Such groups showed more deliberate planning activities than groups without support. Because open suggestions run the risk of not being seriously taken, a specific briefing of the learners should be conducted.

On-line moderation

On-line moderation is an important instructional measure that creates manifold positive effects in terms of preventing problems from developing in net-based collaborative learning. It can help the group to control communication processes,

master co-ordination problems, and initiate and maintain the social exchange (Beaudin, 1999; Ligorio *et al*., 2002). Often, a moderator is necessary to cope with social and emotional conflicts arising in the learning group. In order to point out the potential of on-line moderation, four functions are here differentiated (see Table 1).

Table 1. Moderation functions and measures

Organisation function	Motivation function	Expert function	Didactical function
• Give an overview about the course, make relations between instructional media (print, CBT) and learning forms (group and individual work). • Specify goals for course episodes. • Support formation of groups. • Open and terminate course episodes. • Plan meta communication, e.g. evaluation of the course by the learners themselves. • Inform about performance record and grading.	• Support social presence, e.g. by introduction turns. • Create discussion-favourable climate, e.g. by welcome messages, and encouragement. • Give feedback, e.g. react immediately to each first contribution. • Induce commitment, specify communicative minimum requirements (e.g. minimum number of logins), introduce *netiquette*. • Stimulate curiosity and cognitive conflict, e.g. raise questions, present contradictory positions.	• Supervise suitability of contents and materials regarding curricular goals. • Affect topics according to curricular goals. • Enter additional contents and materials. • Establish subject matter relationships between topics and learning groups. • Make sure that materials are suitably used.	• Give introducing hints / processing assistance for topics. • Stimulate summing up of complex topics or give summaries. • Ask compre-hension questions. • Subdivide a range of topics into sub-tasks, which can be cooperatively worked upon.

The *organisation function* includes measures for organising the learning and working processes. The *motivation function* aims at creating a friendly communication-favourable atmosphere. The *expert function* is to secure the content related quality of net-based learning. The *didactical function* is to give didactical help to ease cognitive processing of the subject matter. In Table 1 appropriate measures are represented for each moderation function. It can be expected that these measures will alleviate problems of net-based learning. For this purpose the moderator can enhance the social exchange of the participants, structure their message exchange by predetermined threads, give hints for the cognitive processing of the subject matter, or stimulate active participation, e.g. by immediate feedback. In spite of all these measures the moderator should take on the role of an advisor instead of trying to steer the group processes too strongly.

Apparently on-line moderation makes great demands on the moderator to take into account all these measures. Moreover, on-line moderation requires different techniques than moderation of face-to-face groups, because many rituals and procedures, which go without saying in face-to-face groups, have to be explicitly stimulated in net-based learning groups. A proper moderator training is advisable to exploit all possibilities of group support (Salmon, 2000).

Learning tasks

An important item of supporting net-based collaborative learning is to choose suitable learning tasks thus fostering motivation, interest and finally the participation of the learners. In doing so one has to consider that net-based collaborative learning aims at social knowledge construction. Yet, for this reason, learning tasks are necessary, which inspire learners to mentally work upon the subject matter, which in turn requires collaboration that can be worked upon with the available communication media. Learning tasks of this kind are markedly complex; they are

project-like and problem oriented, have a strong praxis orientation and require of the learners to take on different points of view. The following learning tasks can measure up to these conditions (Roblyer *et al*., 1997):

- Collaborative topic-related data recall or information search in the Internet with presentation and discussion of the results afterwards.
- Parallel problem solving, at which groups work first independently on the solution of a given problem and then exchanging and discussing their solutions.
- Co-operative project work, with which a project is subdivided into subprojects, which are dealt by individual groups and integrated afterwards.
- Electronic excursions to curricular important places in the net (e.g. cities, landscapes, excavation places, political, cultural, scientific institutions, etc.) and email communication with inhabitants of these places.

With respect to participation one must make sure that the subject matter of such learning tasks is interesting and meaningful for the learners. Moreover, the individual performance should be transparent, because only then can it be prevented that solely the best learners of the group solve the tasks. Additionally, a criterion-oriented group reward can be established, which promotes collaboration (Slavin, 1996). Besides theses measures one has to consider participation to be endangered by the fact that collaborative learning tasks make high demands on the self-organisation of the groups. Groups of learners can be easily swamped, if they form ad hoc, if their members know only a little from each other and if media competency is not yet very pronounced. Therefore the learning tasks should be adjusted to the respective characteristics of the learning scenario and the learning prerequisites of the group members (Friedrich *et al*., 2001a).

Visualisation tools

A promising approach for the promotion of collaborative learning is to provide computer-based visualisation tools (Roschelle & Pea, 1999). These are mapping techniques or graphics tools, which allow the group members to visually illustrate on computer screens the relationships between knowledge-concepts, arguments, or other statements. Such representations can serve the group as an external reference frame for common learning or problem solving. Instructional support concerning the above-mentioned learning problems can be expected by reducing the cognitive load of the learners and enhancing message exchange by precise reference to represented items (Suthers, 1999).

Two types of visualisation tools can be differentiated (Fischer *et al*., 2002): contents-specific and contents-unspecific tools. The latter tools are graphics editors like computer-aided Mind Maps or Shared Whiteboards, which are not fixed to a special knowledge domain. Using such a tool for concept mapping has shown some promising research results with respect to collaborative learning. Van Boxtel *et al.* (1997) found that concept mapping fosters more intensive dialogues between learners. Roth (1994) showed that students emphasise the usefulness of collaborative concept mapping as a learning tool. Technically, contents-specific tools are alike. However, they provide learners with pre-structured visual representations, i.e. both particular categories and relations of the subject matter (Suthers & Hundhausen, 2001). Such tools focus the discourse of the learners on these predicates, but pose constraints on them expressing their thoughts. Fischer *et al.* (2002) on the basis of a comparative study of contents-specific and contents-unspecific visualisation tools

found that the specific tool showed better effects on net-based collaborative learning than the contents-unspecific tool. To account for this result they assume that the focused learning activities by the contents-specific tool, as a form of structured collaborative learning, has contributed to the learning success. Although any research results at all are promising, it should not be overlooked that results primarily relate to learning dyads or small groups. There are no experiences in using such visualisation tools for net-based learning of larger groups. However, within existing applications visualisation tools seem capable of reducing the cognitive load of learners, and assisting in message exchange (Van Bruggen *et al*., 2002).

Outlook

In the future further potential for net-based collaborative learning will appear with the development of information and communication technologies. The increasing possibilities for broadband communication will lead to a widened use of video conference-based learning scenarios, including a lot of supporting measures of technological kind, e.g. tools like Shared Whiteboard, database or document camera (Roschelle & Pea, 1999). Even though emphasis will be placed on text-based communication in the years to come, there will be developments, in this domain, which will support collaborative learning by technological innovations. For example, communication software which graphically highlights: visual patterns, discussion threads, lively discussion phases or the entrance of new members into a working group (Donath *et al*., 1999). There will be chat functions with the improved possibility to represent emotional dimensions by symbol repertoires or choice of colours. Moreover, the use of virtual reality ideas will support collaborative learning, e.g. in the form of simulations or learning scenarios in which learners can immerse themselves as avatars, during their communication with others (Churchill & Snowdon, 1998; Kuljis, 2002). Despite these new technologies and supporting measures there may be many more difficulties in communication and learning, which are hardly foreseeable at the present moment. Instructional science will have to work out suitable instructional supporting measures, which will allow a meaningful usage of these new technologies.

References

Baker, M. & Lund, K. (1997) Promoting reflective interactions in a CSCL environment. *Journal of Computer Assisted Learning*, **13**, 3, 175–193.

Barab, S.A. & Duffy, T.M. (2000) From practice fields to communities of practice. In *Theoretical Foundations of Learning Environments* (eds. D.H. Jonassen & S.M. Land) pp. 25–55. Lawrence Erlbaum, Mahwah NJ.

Beaudin, B.P. (1999) Keeping online asynchronous discussion on topic. *Journal of Asynchronous Learning Networks*, **3,** 2, 41–53. http://www.aln.org/alnweb/journal/Vol3_issue2/Beaudin.pdf

Churchill, E.F. & Snowdon, D. (1998) Collaborative virtual environments: an introductory review of issues and systems. *Virtual Reality: Research, Development and Applications*, **3**, 1, 3–15.

Cohen, E.G. (1994) Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research*, **64**, 1, 1–35.

Dansereau, D.F. (1988) Cooperative learning strategies. In *Learning and Study Strategies: Issues in Assessment, Instruction, and Evaluation* (eds. C.E. Weinstein, E.T. Goetz, P.A. Alexander) pp. 103–120. Academic Press, San Diego.

Dillemans, R., Lowyck, J., van der Perre, G., Claes, C. & Elen, J. (1998) *New technologies for learning: Contribution of ICT to innovation in education*. University Press, Leuven.

Dillenbourg, P. (1999) Introduction: What do you mean by 'collaborative learning'? *Collaborative learning – cognitive and computational approaches* (eds. P. Dillenbourg), pp. 1–19. Pergamon, Amsterdam.

Donath, J., Karahalios, K. & Viegas, F. (1999) Visualizing conversation. *Journal of Computer-Mediated Communication*, **4,** 4. http://www.ascusc.org/jcmc/vol4/issue4/donath.html

Erkens, G., Kanselaar, G., Prangsma, M. & Jaspers, J. (2002) Using tools and resources in computer supported collaborative writing. In *Proceedings of the Conference on Computer Support for Collaborative Learning (CSCL 2002)* (ed. G. Stahl), pp. 389–398. Boulder USA. http://orgwis.gmd.de/~gerry/publications/journals/cscl2002/CSCL%202002%20Proceedings.pdf

Fischer, F., Bruhn, J., Gräsel, C. & Mandl, H. (2002) Fostering collaborative knowledge construction with visualization tools. *Learning and Instruction*, **12**, 2, 213–232.

Friedrich, H.F., Hron, A. & Hesse, F.W. (2001a) A framework for designing and evaluating virtual seminars. *European Journal of Education*, **36**, 2, 157–174.

Friedrich, H.F., Hron, A., Tergan, S.-O. & Jechle, T. (2001b) Unterstützung kooperativen Schreibens in virtuellen Lernumgebungen. [Fostering collaborative writing in virtual learning environments.]. In *E-Text: Strategien und Kompetenzen. Elektronische Kommunikation in Wissenschaft, Bildung und Beruf* (eds. P. Handler) pp. 157–168. Peter Lang, Frankfurt.

Fries, C. (1995) Learner needs in a corporate teletraining environment – evaluation findings in the MTS project. In *Proceedings of the Telematics for Education and Training Conference* (eds. P. Held & W.F. Kugemann), pp. 351–354. IOS Press, Amsterdam.

Harasim, L., Hiltz, S.R., Teles, L. & Turoff, M. (1997). *Learning networks: a field guide to teaching and learning online*. The MIT Press, Cambridge, Mass.

Herring, S. (1999) Interactional coherence in CMC. *Journal of Computer-Mediated Communication*, **4**, 4. http://www.ascusc.org/jcmc/vol4/issue4/herring.html

Hron, A., Hesse, F.W., Cress, U. & Giovis, C. (2000) Implicit and explicit dialogue structuring in virtual learning groups. *British Journal of Educational Psychology*, **70**, 1, 51–64.

Hron, A., Hesse, F.W., Reinhard, P. & Picard, E. (1997) Strukturierte Kooperation beim computerunterstützten kollaborativen Lernen. [Structured cooperation in computer-based collaborative learning.]. *Unterrichtswissenschaft*, **25**, 1, 56–69.

Kirschner, P.A. (2002) Cognitive load theory: implications of cognitive load theory on the design of learning. *Learning and Instruction*, **12**, 1, 1–10.

Kuljis, J. (2002) A distributed virtual collaborative learning environment. In *Proceedings of the 20th IASTED International Conference Applied Informatics.* Innsbruck, Austria. http://www.iasted.org/conferences/2002/austria/workshop/351 ñ610.pdf

Lewis, R. (2000) Human activity in learning societies. Invited paper. In *Proceedings of the International Conference on Computers in Education ICCEI/CCAI 2000, Learning Societies in the new Millennium* (eds. S.S-C. Young, J. Greer, H. Maurer & Y.S. Chee) pp. 36-45. National Tsing Hua University, Taiwan. http://www.public.iastate.edu/~shlin/human%20activity.pdf

Ligorio, M.B., Talamo, A. & Simons, R.-J. (2002) Synchronic tutoring of a virtual community. *Mentoring and Tutoring*, **10**, 2, 137–152.

Littleton, K & Häkkinen, P. (1999) Learning together: Understanding the processes of computer-based collaborative learning. In *Collaborative learning; cognitive and computational approaches* (ed. P. Dillenbourg) pp. 20-30. Elsevier Science, London.

O'Conaill, B. & Whittaker, S. (1997) Characterizing, predicting, and measuring video-mediated communication: A conversational approach. In *Video-Mediated Communication* (eds. K.E. Finn, A.J. Selen & S.B. Wilbur) pp. 107–132. Lawrence Erlbaum, Mahwah NJ.

Paulsen, M.F. (1995) *The online report on pedagogical techniques for computer-mediated communication* [Online document]. http://www.nettskolen.nki.no/.

Reiserer, M., Ertl, B. & Mandl, H. (2002) Fostering collaborative knowledge construction in desktop videoconferencing. Effects of content schemes and cooperation scripts in peer teaching settings. In *Proceedings of the Conference on Computer Support for Collaborative Learning (CSCL 2002)* (ed. G. Stahl) pp. 379–388. Lawrence Erlbaum, Hillsdale NJ.
http://orgwis.gmd.de/~gerry/publications/journals/cscl2002/CSCL%202002%20Proceedings.pdf

Roblyer, M.D., Edwards, J. & Havriluk, M.A. (1997) *Integrating Educational Technology into Teaching*. Merrill / Prentice Hall, Upper Saddle River NJ.

Roschelle, J. & Pea, R. (1999) Trajectories from today's WWW to a powerful educational infrastructure. *Educational Researcher*, **28**, 5, 22–25. + 43.

Roth, W.-M. (1994) Student views of collaborative concept mapping: An emancipatory research project. *Science Education*, **78**, 1, 1–34.

Salmon, G. (2000) *E-moderating: the key to teaching and learning online*. Kogan Page, London.

Saunders, W.M. (1989) Collaborative writing tasks and peer interaction. *International Journal of Educational Research*, **13**, 1, 101–112.

Schwan, S., Straub, D. & Hesse, F.W. (2002) Information management and learning in computer conferences: Coping with irrelevant and unconnected messages. *Instructional Science*, **30**, 4, 269–289.

Slavin, R.E. (1996) Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary Educational Psychology*, **21**, 1, 43–69.

Suthers, D.D. (1999) *Representational support for collaborative inquiry*. In *Proceedings of the 32nd Hawaii International Conference on System Sciences (HICSS-99)* (ed. R.H. Sprague). IEEE Computer Society Press.
http://www.computer.org/proceedings/hicss/0001/00011/00011076.pdf

Suthers, D.D. & Hundhausen, C.D. (2001) Learning by constructing collaborative representations: An empirical comparison of three alternatives. In *European Perspectives on Computer-Supported Collaborative Learning* (eds. P. Dillenbourg, A. Eurelings & K. Hakkarainen) pp. 577–592. University of Maastricht, Maastricht.

Swan, K., Shea, P., Fredericksen, E., Pickett, A., Pelz, W. & Maher, G. (2000) Building knowledge building communities: consistency, contact and communication in the virtual classroom. *Journal of Educational Computing Research*, **23**, 4, 389–413.

Sweller, J., van Merrienboër, J.J.G. & Paas, F.G.W.C. (1998) Cognitive architecture and instructional design. *Educational Psychology Review*, **10**, 3, 251–296.

Van Boxtel, C., van der Linden, J. & Kanselaar, G. (1997) Collaborative construction of conceptual understanding: Interaction processes and learning outcomes emerging from a concept mapping and a poster task. *Journal of Interactive Learning Research*, **8**, 3/4, 341–361.

Van Bruggen, J.M., Kirschner, P.A. & Jochems, W. (2002) External representation of argumentation in CSCL and the management of cognitive load. *Learning and Instruction*, **12**, 1, 121–138.

Webb, N.M. & Palinscar, A.S. (1996) Group processes in the classroom. In *Handbook of Educational Psychology* (eds. D.C. Berliner & R.C. Calfee) pp. 841–873. MacMillan, New York.

Weinberger, A., Fischer, F. & Mandl, H. (2002) Fostering computer supported collaborative learning with cooperation scripts and scaffolds. In *Proceedings of the Conference on Computer Support for Collaborative Learning (CSCL 2002)* (ed. G. Stahl) pp. 573–574. Lawrence Erlbaum, Hillsdale, NJ.
http://orgwis.gmd.de/~gerry/publications/journals/cscl2002/CSCL%202002%20Proceedings.pdf