Instructional Science **32:** 475–502, 2004.

Interaction and cognition in asynchronous computer conferencing

SARAH SCHRIRE
English Department, Centre for Educational Technology, 16 Klausner Street, Tel Aviv 61394, Israel and Computers in Education Department, Kibbutzim College of Education, 149 Namir Road, Tel Aviv, Israel (E-mail: shrire@netvision.net.il)

Received in final form: 21 August 2003; accepted: 25 August 2004

Abstract. This paper is based on a multiple-case study of the learning process in three asynchronous computer conferences. The conferences were part of the distance learning component in doctoral degree courses in computing technology in education offered at an American university. The conferences were analyzed from a number of perspectives, the emphasis in this paper being on the dimensions of interaction and cognition. Although similar interaction patterns were identified in the three conferences, each conference also showed distinctive patterns, which were related to factors such as instructor moderation, structuring of the instructional task and the emergence of student moderation of the discussion in specific threads. Three models were used to evaluate cognition: Bloom's Taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, Handbook 1, Cognitive Domain, Longman, London, 1956), the SOLO Taxonomy (Biggs & Collis, Evaluating the Quality of Learning: The SOLO Taxonomy, Academic Press, New York, 1982) and the Practical Inquiry Model of Cognitive Presence (Garrison, Anderson & Archer, The American Journal of Distance Education 15(1)7, 2001). Correspondences were found among the three models and all three conferences were characterized by higher-order thinking. When higher-order thinking was defined in terms of the distributed cognition occurring during practical inquiry, the advanced phases of cognition were found to be related to synergistic interaction in the conference threads. The findings serve to define the knowledge-building processes occurring in asynchronous computer conferencing. They also lend support to views of learning as dialogical and to social constructivist approaches to learning and teaching.

Keywords: cognition, collaboration, computer conferencing, interaction, knowledge-building, online discussion, online learning

Introduction

Asynchronous computer conferencing constitutes the core of many current distance education courses and forms the basis for the creation of learning communities that can overcome barriers of time and place. Distance education courses that are structured as learning communities represent the change from the industrial correspondence course model of distance education to a networked model of online collaborative

learning. Garrison (1997) discusses many of the benefits of computer conferencing in education, the most important being the relationship between written communication and cognitive development. This relationship is attributed to the effect of writing on thinking, and to the suitability of collaborative learning to higher-order thinking and to the development of a deep and meaningful approach to learning.

According to Anderson and Garrison (1997), the independence and isolation that characterized the industrial era of distance education are being challenged by the collaborative approaches to learning made possible by learning networks. Such approaches emphasize the quality of the learning experience, the development of skills needed for the critical evaluation of information and the collaborative construction of knowledge and actions. Hiltz (1998) identifies two models of asynchronous learning. Although both make use of the Internet to deliver "anywhere, anytime" learning, the first is the mass model of one-way instructional delivery whereas the second is one of a collaborative learning community. The focus of the investigation reported in this paper is on the latter.

The investigation was conducted within the qualitative paradigm of case study research (Creswell, 1994; Stake, 1995; Merriam, 2001) and involved the analysis of the learning process in three asynchronous computer conferences (Schrire, 2002). Each of the conferences was a significant component of the virtual classroom in a doctoral study program on computing technology in education. The study program combined online and face-to-face instruction.

Review of literature

Depth of learning has been defined and examined in various ways in the educational and cognitive psychology literature, depending on theoretical orientation and investigative locus. The Taxonomy of Educational Objectives (Bloom et al., 1956) draws attention to potentials for achieving different levels of cognitive performance in the learning process, with *analysis*, *synthesis* and *evaluation* characterizing the upper levels. In two pioneering studies examining the quality of learning in tertiary education, Marton and Saljo (1976a, 1976b) differentiated between deep and surface processing of material studied. Building on Marton and Saljo's investigations, Biggs and Collis (1982) differentiated between in-depth and surface processing in a taxonomy for assessing the structure of observed learning outcomes (SOLO). Watkins (1983), Boulton-Lewis (1998), Dart (1998) and Hattie and Purdie (1998) used

the SOLO Taxonomy to measure the structural complexity of knowledge construction in the learning products developed by students. Quellmalz (1985) discusses the cognitive processes underlying higher-order thinking. Ennis's work (1989) focuses on the development of critical thinking and Boulton-Lewis (1998) identifies higher-order thinking with critical thinking.

Findings from the fields of educational and cognitive psychology have provided a starting-point for research investigating knowledge-building and cognition in computer conferencing. Henri (1992), Henri and Rigault (1996) and Hara, Bonk and Angeli (2000) differentiate between surface and in-depth cognitive processing in their research of the learning process in computer conferencing. Both Quellmalz's and Ennis's concepts are incorporated into Henri's content analysis model, which has been applied in much of the computer conferencing research. Aspects of Henri's model were applied by Newman, Johnson, Cochrane and Webb (1996) in their study of critical thinking in university level seminars and by McDonald and Gibson (1998) in their investigation of interpersonal dynamics in computer conferencing. In a study of online computer conferencing involving graduate students, Aviv (2000) operationally defined the learners' cognitive strategies in terms of Henri's model.

There is a growing base of theory and research on the centrality of collaboration, especially online collaboration, to depth of learning and knowledge-building. Harasim (1987) makes the point that debate and dialogue are particularly relevant to graduate education. Eastmond (1992) characterizes the online instructional environment as conducive to topical discussion, group interactions, synthesis of ideas and learner reflection. Looking at the potentials of computer conferencing in distance education from a social constructivist perspective, McDonald and Gibson (1998) describe it as a powerful learning tool because of its capability to support interaction and collaboration among diverse and dispersed students. Anderson and Garrison (1998) refer to the potentials of asynchronous computer conferencing in the support of collaborative learning in that these provide opportunities for deliberation and reflection. Abramson (1999) analyzes instructional discourse among doctoral students in an asynchronous forum, calling the asynchronous distance learning classroom a collaborative mindtool. The sample forum entries presented by Abramson are a reflection on the medium and on its contribution to the development of critical thinking and effective communication.

Paralleling the increased adoption of computer conferencing within distance learning courses, there has been a growing body of work investigating computer-supported collaborative learning and computer-supported

intentional learning environments (CSILEs). These investigations are based on views of knowledge as constructed by, rather than transmitted to, the learner (Scardamalia & Bereiter, 1993, 1994, 1996; Pea, 1993, 1994; Jonassen, 1994; Jonassen, Davidson, Collins, Campbell & Haag, 1995; Jonassen, in Gibson, 1998).

Scardamalia and Bereiter (1993, 1994, 1996) compare learning to the knowledge-building process in the scientific community, as expressed in Popper's conception of the cumulative development of scientific thought by conjecture and refutation. These ideas are at the basis of their CSILEs, where knowledge-building discourse focuses on problem solving, depth of understanding, decentralized, open learning and the support of small-group interaction. The use of dialogic questions in the instructional process is emphasized. Similar ideas underlie Campos's (1998) research on the role of conditional reasoning in asynchronous computer conferencing, where the conditional reasoning processes of concept building and rebuilding were found to scaffold the mixed-mode discussion groups he studied. Campos describes computer conferencing messages as expressions of mental processes through which meaning is built and rebuilt, reflecting a view of computer conference transcripts as objects of knowledge.

Brown and Palinscar (1989) similarly place an emphasis on the role of collaboration in knowledge-building, although not in the context of electronic learning. According to them, group settings foster conceptual change and restructuring via questioning, criticism and evaluation. Citing Toulmin, they explain that knowledge-building is inherent in the structure of conversations and debates since these force the participants to produce explanations, interpretations, and resolutions to problems.

According to social construction theorists, learning is necessarily a dialogical process in which communities of practitioners socially negotiate the meaning of phenomena. Jonasssen et al. (1995) refer to learning as conversation, and they consider the thinking and intelligence of a community of performers or learners as distributed throughout the group. Similar ideas are expressed by Resnick (1991) and Perkins (1993). Perkins has developed the concept of intelligence as manifested in the ''person-plus,'' i.e., cognition as distributed between the ''person-solo'' (the individual learner) and the ''surround'' (the total learning context). Salomon (1993) emphasizes the interplay between individual and distributed cognitions.

The concepts of distributed intelligence and distributed cognition necessarily change the object of research from individual learning to collaborative learning. In keeping with such an emphasis, Gunawardena, Lowe and Anderson (1997) and Garrison, Anderson and Archer

(2000, 2001) have made sociocognitive processes, rather than individual cognitive processes, the object of their investigations. Gunawardena et al. describe the shared knowledge-building process occurring in online computer conferencing as a quilt woven by all the participants, a graphic metaphor that effectively illustrates the interaction analysis model they developed. Garrison et al.'s view of a computer conference as a community of critical inquiry underlies their Practical Inquiry Model of Cognitive Presence, proposed for the analysis of collaborative knowledge-building in computer conferencing. In a community of critical inquiry, the learning of the individual is both dependent on, and arises out of, the learning of the group or community. Instructional conferences go through a number of phases as collaborative, dialogical inquiry develops, beginning with one or more *triggering events* and continuing through the phases of *exploration*, *integration* and *resolution*. Garrison et al.'s concept of cognitive presence was applied by Deziel-Evans (2000) in an investigation comparing critical thinking in synchronous and asynchronous online learning environments for doctoral degree pharmacy students. Deziel-Evans defines the higher levels of critical thinking in terms of the *integration* and *resolution* phases described by Garrison et al. (2000) and as elaborated in Garrison et al. (2001).

The research questions posed in many of the above studies attempt to characterize what has been learned and how understanding has evolved during the learning process in asynchronous computer conferences. This is the direction recommended by Hannafin and Kim (2003) in their analysis of web-based teaching and learning. The study reported in this paper fits the same research perspective.

Theoretical roots

Views of asynchronous computer conferences as environments conducive to the collaborative or dialogic construction of knowledge are based on the essentially verbal nature of asynchronous communication. The dialogic approaches of Vygotsky (1962, 1978), Wells (1996, 1999) and others provide a theoretical basis from which collaborative processes in online learning can be understood. Central to Vygotsky's ideas on the relation between language and thought is his observation that language does not merely express thought but is a vehicle for the formation of thought. Thought is activity that has become mediated by signs, which are the building blocks of language and, during individual development, interpersonal processes become internalized and are transformed into intrapersonal processes.

According to Vygotsky (1978), all the higher functions – attention, memory and the formation of concepts – originate as relations between individuals. The mediation of activity by the combined use of tools and signs is what characterizes higher mental processes. Gunawardena et al. (1997), mentioned above, apply Vygotsky's distinction between lower and higher mental functions to the analysis of co-constructed knowledge. They point out that when knowledge is co-constructed, it is necessary to determine group learning processes and to view the interaction as a whole. Their proposed interaction analysis model represents a way of analyzing distributed cognition in computer conferencing. Similarly appropriate ways of operationalizing the above theoretical concepts are represented by Garrison et al.'s (2000, 2001) Practical Inquiry Model, also described above.

Vygotsky's (1962, 1978) ideas on the primacy of language in the development of mental functioning are taken further by Wertsch (1991, 1998), who sees dialogism as central to the understanding of human action. Wertsch speaks of individual(s)-acting-with-mediational-means rather than of individuals in isolation. In keeping with this holistic perspective is Wertsch's (1991) observation that research geared to understanding human action should use a unit of analysis that preserves in microcosm as many dimensions of the general phenomenon under consideration as possible. This has implications for research that focuses on learning as a collaborative process since the unit of analysis has to allow the researcher to move from one dimension to another without losing sight of how the various dimensions fit together into a more complex whole.

Learning as conversation

The sociocultural conception of cognitive development (Vygotsky, 1962, 1978; Wertsch, 1991, 1998) provides a theoretical framework for research that has as its focus dialogue and conversation. Jenlink and Carr (1996) present a useful classification of what they call educational conversations. Their classification differentiates between dialectic conversations, discussion conversations, dialogue conversations and design conversations.

Each type of conversation leads to the construction of a different kind of knowledge, representing different degrees of openness to the ideas of others. Each type of conversation has one or more different purposes: transacting (negotiating within an existing problem setting), transforming (in the sense of being open to a transformation of one's

own beliefs) and transcending (where the purpose is to move out of existing mindsets to create a new perspective on something). These ideas are taken further by Sherry, Billig and Tavalin (2000), who consider how a model of learning as conversation can help to clarify what takes place in online learning interactions and provide a means to improve the instructional interactions.

A view of learning as conversation suggests a connection between the interactive, cognitive and discourse dimensions of collaborative learning and provides a basis for analyzing the moderation of educational conversations. This view was at the basis of the research questions underlying the study reported in this paper. Two of the initial research questions are relevant to this paper, as is a third question, which arose during the case analyses. The three questions focus on the interactive and cognitive dimensions of learning:

1. What patterns of interaction can be found in asynchronous online computer conferences?
2. What kinds and levels of individual and socially distributed cognition characterize the learning process in asynchronous online computer conferences and their component threads?
3. How are interaction and cognition connected in asynchronous online computer conferences?

Methodology

Design

A case study design was chosen since it enabled a qualitative and holistic analysis of the learning process in asynchronous computer conferencing. The case study design fitted the theoretical framework of the research and the nature of the phenomenon investigated, which involved an emphasis on process rather than outcome (Gay, 1996; Merriam, 2001).

Three computer conferences were studied, each representing a single case. Each case was first studied separately, then cross-case comparisons were made. The first case (referred to as Forum 1 in subsequent parts of this paper), represents the full case study in the investigation. The other two cases (referred to as Forums 2 and 3), were partially analyzed in order to answer questions that arose in the study of the first case.

Embedded within each case study were multiple units of analysis, ranging from the computer conference as a whole, to the discussion thread, through to the smaller units such as messages and speech

segments. What is characterized by Yin (1984) as a multiple-case embedded design was appropriate to the multi-level analysis carried out.

Sampling procedure

The three selected cases were asynchronous computer conferences in doctoral degree courses offered by the Graduate School of Computer and Information Sciences at Nova Southeastern University in the United States. The conferences were selected from a pool of nine semester-long courses in computing technology in education that took place between January 2000 and August 2001. The courses in the pool combined face-to-face learning and online instruction, and asynchronous online discussion was one of the significant aspects of the distance learning component. The conferences were analyzed retrospectively.

Case selection was done by purposive sampling (Merriam, 2001). The first case, Forum 1, represents a *typical case* (Miles & Huberman, 1994) of an actively instructor-moderated conference. The instructor opened the discussion, posted opening questions, responded to students' messages throughout the conference and summed up main points during and at the end of the conference. Forum 2 was tentatively chosen on the basis of what Miles and Huberman refer to as *maximum variation* from Forum 1 since it represented an alternative approach to instructor intervention. The instructor was responsible for opening and closing the conference and structuring the discussion task at the outset by defining the question and rules for participation. Whereas Forum 1 was characterized by instructor intervention throughout the discussion, Forum 2 had no instructor intervention beyond the instructor's opening and closing messages. The final decision about the inclusion of Forum 2 was made sequentially, during the data analysis of Forum 1, when more information became available on which to base the sampling decisions. The decision about the inclusion of Forum 3 was made during advanced stages of the data analysis of Forums 1 and 2, and arose from the need to examine an aspect of conferencing interaction found to be absent in the first two forums (spontaneous student moderation). The sequential sampling procedure described above is often characteristic of purposive sampling (Yin, 1984).

Instruments and coding

Coding and content analysis were carried out for each of the three conferences and the results were presented as individual case studies. Trends across the three cases were discussed at the interpretive level. In

each case study, the dimensions of interaction and cognition were first examined separately, then in relation to each other. The following description represents the coding and content analysis of Forum 1. More limited analyses were done of Forums 2 and 3.

To answer the first research question, presented above, the *interactive dimension* of the learning process was examined using a mapping technique similar to that described by Howell-Richardson and Mellar (1996) and Hara et al. (2000). The interaction pattern mapping gave a visual representation of the discussion threads making up the conference, the clusters of messages interacting with one another around sub-topics of the conference.

The following steps were taken to create the visual map:

1. The entire discussion was read from beginning to end in order to get a general impression of the conversation. Each message was accorded a number according to its position in the chronology of the conference.
2. The "interaction space" of the conference was visually depicted by representing each message as a circle with its corresponding number, and using arrows to show messages connected by *explicit* or *implicit interaction* (Henri, 1992). In *explicit interaction*, a message contains explicit reference to the author or content of another message; in *implicit interaction*, the connection is implied and has to be inferred.
3. To facilitate easy "reading" of the interaction pattern map, instructor messages were visually differentiated from student messages by use of a double border.
4. Message clusters, i.e., messages that were in interaction with one another around a sub-topic of the discussion, were visually represented on the interaction pattern map, showing the "knowledge space" of each topical thread.
5. The interaction pattern map necessitated more than one page, showing in two dimensions what may have been better depicted via a three-dimensional model. A message relating to a previous message in a thread depicted on another page contained a smaller circle representing the message related to.
6. The interaction pattern map was scanned for important information, such as the intensity of activity in the component threads, the presence of distributed versus centralized interaction, messages that had become "nodes" of interaction, and messages that had not been responded to and that had remained isolated in the "discussion space." This information was used in the subsequent analysis.

7. Threads within the forum were selected for analysis on the basis of distinctive or important features that became apparent from the interaction pattern map, e.g. more interactive threads versus less interactive threads, or threads showing one-way versus multi-directional interaction. Interaction pattern mapping was therefore an important part of the *thread* sampling procedure in the conference and of the subsequent data analysis.

Following the visual mapping, it was possible to classify the thread types within the conference. This provided a basis for coding the messages on the *cognitive dimension* and comparing cognitive patterns among the thread types. The analysis of cognition was done in order to answer the second research question, presented above. By considering cognition in relation to the interaction pattern characterizing each thread type, it was possible to answer the third research question.

Three instruments were used for analyzing cognition: Bloom's Taxonomy of Educational Objectives for the Cognitive Domain (Bloom et al., 1956), the SOLO Taxonomy (Biggs & Collis, 1982) and the Practical Inquiry Model of Cognitive Presence (Garrison et al., 2000, 2001). As described earlier, each of these instruments emphasizes a different aspect of cognition. Whereas the Bloom and SOLO taxonomies measure individual cognition, the Practical Inquiry Model additionally presents a picture of socially distributed cognition. The decision to use instruments measuring both individual and socially distributed cognitive processes was based on the rationale outlined in a previous section regarding the complementary nature of individual and socially distributed cognitions.

Using Bloom's Taxonomy to measure the level of cognitive performance, each conference message was coded on one of the following categories: *knowledge*, *comprehension*, *application*, *analysis*, *synthesis* and *evaluation*. The categorization made it possible to distinguish between lower-order and higher-order thinking. The data were analyzed in terms of two possible cutoff points: with higher-order thinking starting from *analysis*, and with higher-order thinking starting from *synthesis*.

On the SOLO Taxonomy, messages were coded for structural complexity as showing *prestructural*, *unistructural*, *multistructural*, *relational* or *extended abstract* levels. Higher-order thinking was defined as including the *relational* and *extended abstract* levels.

Messages were coded according to the four phases comprising the Practical Inquiry Model of Cognitive Presence. In this model, knowledge-building is considered to be both an individual and a group learning process involving collaboration among learners. Participants in

an instructional computer conference move through four phases identified by Garrison et al. (2001): (a) from the shared world of practical experience (involving a *triggering event*, usually initiated by the instructor or moderator); (b) through an inductive and divergent process of learning *exploration* leading to awareness of aspects of the issue or problem; (c) followed by a convergent process of reflection and deliberation (where *integration* takes place); (d) ending in a commitment to solutions that are tested by a deductive process of discourse (*resolution*). The phases of critical inquiry can best be described as representing a spiral movement, which can continue to a new *triggering event*. In the above scheme, the third and fourth phases, *integration* and *resolution*, represent the higher levels of critical inquiry.

A minimum of 40% of the messages on each instrument was independently coded by two raters and inter-rater agreement was determined using Holsti's (1969) coefficient of reliability (CR). Discrepancies in the raters' coding were discussed by the raters and the investigator until consensus was reached.

Results

The findings on interaction and cognition for the full case study, Forum 1, are detailed in this section. Related results from Forums 2 and 3 are referred to as necessary.

Forum 1 was the main reflective computer conference in a doctoral course on Instruction Delivery Systems. The conference lasted for a period of just under 15 weeks, from January 31st to May 12th, 2000, and focused on pedagogical issues in ICT. None of the questions that led to the online discussion had straightforward or "correct" answers, but represented opportunities for deliberation and the exchange of ideas. Participation in the conference was encouraged by the instructor but was not mandatory. The conference included 12 student participants and the instructor, who was the conference moderator. Descriptive data for this conference are listed in Table 1.

The interaction pattern mapping showed that the conference interactions constituted 13 discussion threads, 12 of which had been initiated by the instructor and one by a student. Analysis of the cognitive components was performed on 11 of the 13 threads, referred to as threads 1–11. Thread 12, the student-initiated thread in this conference, was omitted from the analysis of cognition, as was thread 13. Both were atypical for this conference and could not be grouped with any of the other threads to warrant comparative analysis within the conference.

Table 1. Forum 1: descriptive data

Threads	Number of instructor messages	Number of student messages	Total number of messages
Total: 13	29	80	109
Analyzed: 11	23	64	87

Interaction patterns

The interaction pattern mapping for Forum 1 is shown in Figures 1–3. Instructor and student messages are depicted by circles, those with bolded borders representing the instructor messages. Messages responding to other messages explicitly or implicitly were connected, the direction of interaction being shown by arrows. A dotted line was used when interaction was possibly present but could not be definitively established.

On the basis of the interaction pattern mapping, it was possible to characterize the 13 threads in Forum 1 according to five interaction pattern types: (a) *instructor-centered*, with responses initiated and triggered by an instructor message and responding mainly to the instructor message; (b) *synergistic*, including responses to the initiating message as well as follow-ups by conference participants from one message to another; (c) *developing synergism*, with mixed characteristics of instructor-centered and synergistic interaction; (d) *scattered*, involving small separate message clusters around loosely related sub-topics; (e) *student-centered*, with responses initiated by a student message.

Interaction that is *instructor-centered* or *student-centered* is similar to what Lipponen, Rahikainen, Lallimo and Hakkarainen (2003) describe as centralized interaction and to what Hara et al. (2000) characterize as starter-centered interaction, where ''starters'' are responsible for initiating discussion. In Hara et al.'s study, students played the role of starters, whereas in the study that is the subject of this paper, the instructor was the starter in all but one thread. Instructor-centered and student-centered interaction may be visually represented as the spokes of a bicycle wheel, with all interaction directed toward the center. Six of the 13 conference threads in the reported study were of this nature: Threads 1–3, 7 and 9 (instructor-centered) and Thread 12 (student-centered). These were also threads with less activity than others, especially Threads 1–3, 7 and 12, each of which contained a small number of messages. Threads 1–3 were all begun in the early stages of the conference.

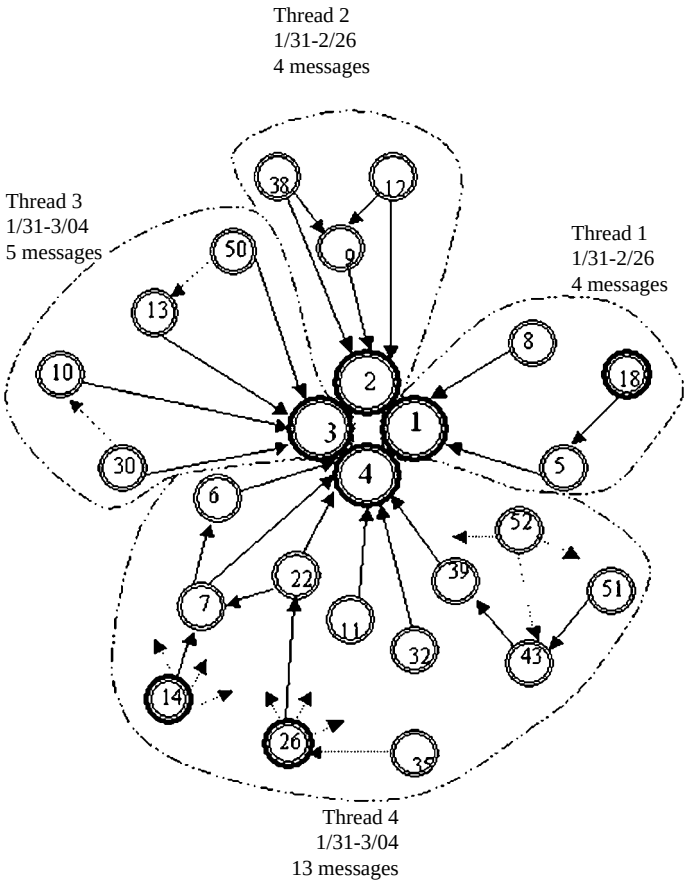

Figure 1. Interaction patterns in Forum 1 (Threads 1–4).

Synergistic interaction, also found in Hara et al.'s (2000) analysis, is described as interaction where every message is connected to another, either directly or indirectly. Lipponen et al. (2003) call this distributed interaction. This is the pattern that characterized Threads 5, 8 and 11. Such a pattern points to a collaborative learning process, where responses are dependent on one another, in contrast with the more "solo" type of learning that characterized the *instructor-centered* threads described above.

Threads 4, 6 and 10, which contained characteristics of both instructor-centered and synergistic threads, were characterized as showing *developing synergism*. Thread 13 was the only thread in Forum 1 showing *scattered* interaction. Scattered interaction was similarly found and defined by Hara et al. (2000). This pattern could have been caused either by the late period (the last two weeks) of this stage of the

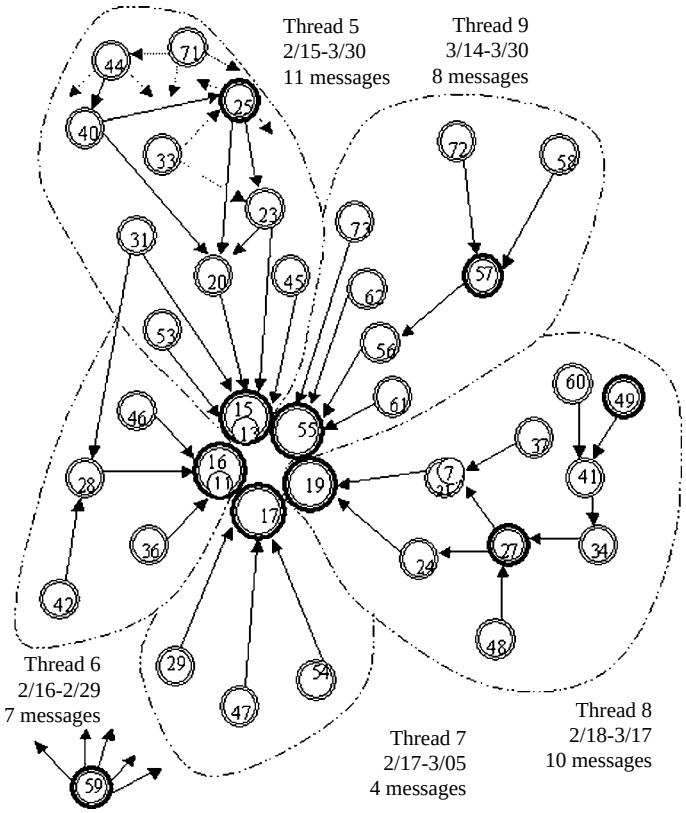

Figure 2. Interaction patterns in Forum 1 (Threads 5–9).

conference or by the lack of a unifying topic base to the discussion thread. The thread consisted of disparate questions and comments relating to a variety of listserv postings.

Aside from Threads 12 and 13, which were atypical for this conference, it is possible to characterize Forum 1 as having three types of interaction: *instructor-centered*, *synergistic* and *developing synergism*. Whereas instructor-centered threads could be contrasted with synergistic threads, the threads showing developing synergism formed a bridge between the two types. The synergistic Threads 5, 8 and 11 represented learning interaction patterns where collaborative knowledge-building appeared to have taken place, at least on the dimension of interaction.

The interaction pattern mapping also showed the presence of cross-thread connections, initiated both by the instructor and the students. Lipponen et al. (2003) refer to this as sustained interaction. The cross-thread connections between threads 3, 5 and 6 are depicted in

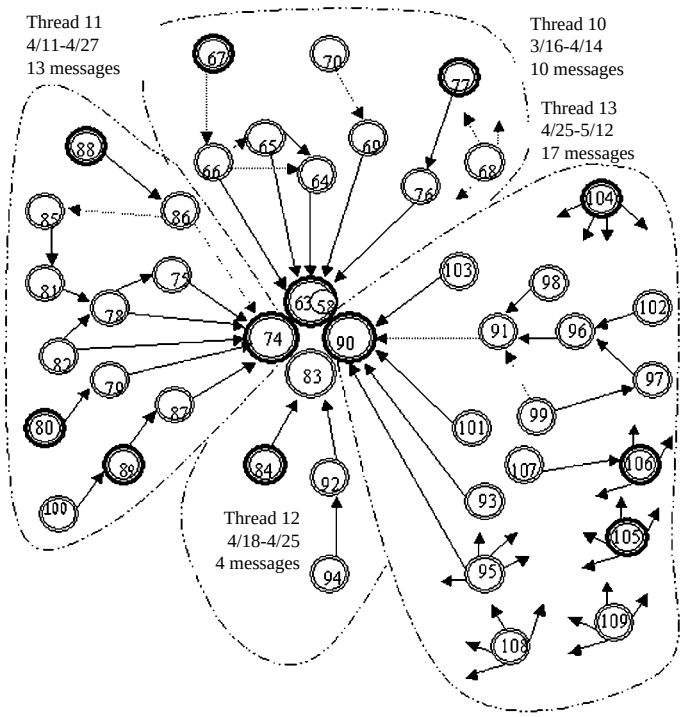

Figure 3. Interaction patterns in Forum 1 (Threads 10–13).

Figure 4, which presents a different kind of "section cut," or view, of the conference threads.

Figure 4 shows that the instructor's message initiating the discussion in Thread 5 (message 15) was related to an aspect of a student's message in thread 3 (message 13), creating a continuation of the earlier discussion. Figures 1–3 show evidence of similar patterns throughout the conference: in Thread 6, the instructor's initiating message carried over a point from a student's message in Thread 4; and in Thread 10, the instructor took up a point raised by a student in Thread 9. Such cross-thread interactions reflect part of the moderator's role in sharpening the focus of a topic or deepening the dialogue (Collison, Elbaum, Haavind & Tinker, 2000) and are discussed in Schrire (2002). Figure 4 also shows cross-thread interaction between student participants (message 31, reacting to a point in message 28 in Thread 6, which was taking place concurrently). Figures 1 and 2 show a similar occurrence of cross-thread interaction between student participants (message 21 in thread 8 relating to message 7 in Thread 4).

The interaction analysis of Forum 2 revealed a number of trends, which can be understood in terms of how the instructor had defined

the instructional task and specified the participation requirements. The findings that are of specific relevance here are: (a) the presence of two *synergistic* threads, similar to those found in Forum 1, but containing an additional "layer," where student messages posted in response to the initial instructor message became the bridge to the subsequent student messages and follow-ups; (b) the presence of a large number of short threads, which as a group could be described as representing a *scattered* pattern of interaction; (c) the presence of a large number of isolated or *solo* messages responding to the initial instructor message.

The interaction analysis of Forum 3 similarly revealed the presence of *synergistic* threads and shorter threads representing *scattered* interaction. An additional interaction pattern was identified in Forum 3 – a *message chain* type, where each message answered a previous one, but without much interaction in other directions. Of relevance to conferencing moderation, all but one of the threads in Forum 3 were initiated by students, as a second "layer" in response to the instructor's opening message. Two of the student-initiated discussions showed interventions by the student who had started the discussion, including a sum-up message. These two threads therefore contained spontaneous student moderation of the discussions, including "starting" and "wrapping."

To sum up the findings relating to interaction in all three conferences, patterns included the following interaction types: *instructor-centered*, *student-centered*, *synergistic*, *developing synergism*, *scattered* and *message chains*. Isolated, or *solo* messages, could also be found within the computer conferences. The interaction type indicating collaborative learning processes was the *synergistic* pattern.

Cognition

The findings related to cognition point to the presence of higher-order thinking in all three conferences investigated. Forums 1 and 2 were characterized by higher-order thinking on the three instruments described earlier: Bloom's Taxonomy, the SOLO Taxonomy and the Practical Inquiry Model of Cognitive Presence. Forum 3 was characterized by higher-order thinking on the Practical Inquiry Model, the only instrument used in the analysis of this conference. Inter-rater agreement using Holsti's CR was *fair* to *moderate*, ranging from 0.55 to 0.74, values considered acceptable for the content being coded. Discrepancies were discussed and reviewed. Where agreement between the raters could not be reached, the messages were categorized as *uncodable*.

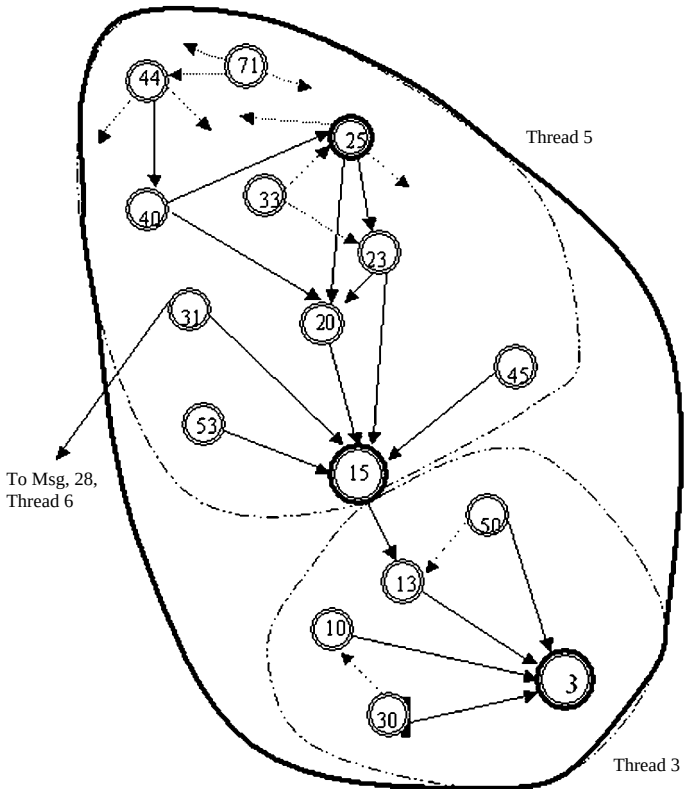

Figure 4. Cross-thread interactions in Forum 1.

In Forum 1, 59% of the messages were categorized at the upper levels of Bloom's Taxonomy, showing *analysis*, *synthesis* or *evaluation* (compared to 36% at the lower levels). On the SOLO Taxonomy, 62% of the messages reflected structural complexity at the *relational* or *extended abstract* levels (compared to 33% at the lower levels). On the Practical Inquiry Model, *integration* and *resolution*, which accounted for 42% of the messages, were in balance with *exploration*, which accounted for 41% of the messages. The full results for all three conferences are reported in Schrire (2002).

The Practical Inquiry Model was found to be the most relevant to the analysis of the cognitive dimension and presents a clear picture of the knowledge-building processes occurring in online discussion. The findings using the Practical Inquiry Model in the coding of the messages in Forum 1 are presented in Figure 5. As shown in Figure 5, the conference discussion was evenly distributed between the phases of *exploration* on the one hand, and *integration* and *resolution* on the other.

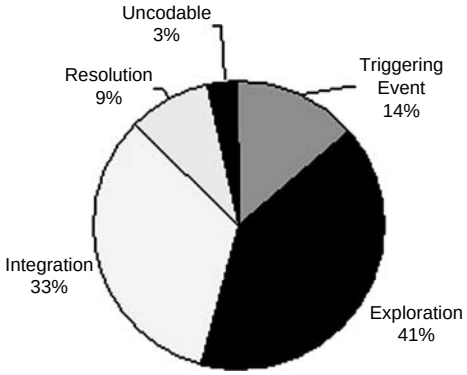

Figure 5. Forum 1: socially distributed cognition, based on Garrison et al. (2001).

Higher-order thinking, involving the phases of *integration* and *resolution*, accounted for approximately half of the messages responding to the *triggering events*.

Forum 2 showed an even higher proportion of higher-order thinking on the basis of the Practical Inquiry Model than Forum 1: 56% of the messages were at the phases of *integration* and *resolution*, compared to 29% of the messages at the phases of *exploration*. In Forum 3, 49% of the messages showed *integration* and *resolution*, compared to 35% showing *exploration*. An additional proportion of the messages in each conference comprised *triggering events* or *uncodable* messages.

To sum up the findings on cognition for all three conferences, higher-order thinking was present in between half to two-thirds of the messages. In the two conferences where three instruments were used to measure higher-order thinking, the findings applied on all three measures.

Interaction and cognition

In order to establish how higher-order thinking was a function of the collaborative knowledge-building process in the computer conferences, the cognitive dimension was examined in relation to the interactive dimension. This was done by comparing cognition in each of the main thread interaction types within each conference. In Forums 1 and 2, which were fully analyzed from this perspective, the findings based on the Practical Inquiry Model showed a connection between the thread interaction pattern type and the phase of critical thinking.

In Forum 1, higher-order thinking as defined by the Practical Inquiry Model was associated with synergistic interaction more than with other types of interaction. Comparing the main thread types found in Forum 1 (instructor-centered, developing synergism, and synergistic) on the four phases of practical inquiry, it was possible to identify a trend toward greater integration and resolution as threads became more synergistic. Instructor-centered threads contained a smaller proportion of messages showing *integration* and *resolution* (24%) compared to messages showing *exploration* (56%). However, threads developing synergism contained more messages showing *integration* and *resolution* (46%) than *exploration* (39%). Synergistic threads had an even higher proportion of messages showing *integration* and *resolution* (53%) relative to *exploration* (29%). *Triggering events* ranged from 11% to 20% across the thread types.

Using Pearson's Chi-Square, synergistic threads were found to differ significantly from instructor-centered threads on a classification differentiating between *exploration* on one hand and *integration* and *resolution* on the other (χ^2 [1, $n = 48$] = 5.49, $p < 0.05$). Comparisons using different combinations, such as between instructor-centered threads and threads developing synergism, were not statistically significant.

Figure 6 shows the association between interaction and cognition described above. The findings based on the Practical Inquiry Model were corroborated by the case analysis of Forum 2, where synergistic threads were found to differ significantly from the other thread interaction types (χ^2 [2, $n = 60$] = 6.84, $p < 0.05$) on Pearson's Chi-Square.

The more limited investigation of Forum 3 suggested similar trends to those described above. Taken together, the findings based on the Practical Inquiry Model point to a relationship between collaborative interaction and the cognitive processes occurring in the spiral of practical inquiry in instructional computer conferences.

The relationship between interaction and cognition based on the Bloom and SOLO taxonomies was less clear-cut than with the Practical Inquiry Model. In Forum 1, using Bloom's Taxonomy, synergistic threads showed significantly higher levels of cognitive performance than instructor-centered threads (χ^2 [1, $n = 40$] = 4.41 $p < 0.05$). However, no significant differences were found using the SOLO Taxonomy. On the other hand, in Forum 2, synergistic threads showed significantly higher levels of in-depth processing than other thread types on the SOLO Taxonomy (χ^2 [2, $n = 54$] = 8.62, $p < 0.05$) but there were no significant differences in levels of cognitive performance on Bloom's Taxonomy. Possible reasons for these discrepancies are discussed below.

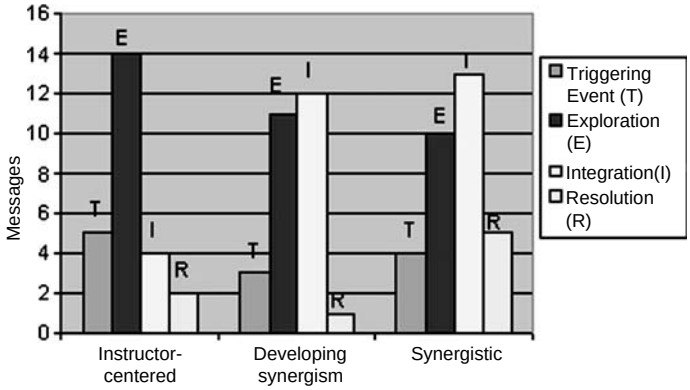

Figure 6. Forum 1: interaction type and phases of cognitive presence, based on Garrison et al. (2001).

Discussion

The main contribution of the study reported in this paper lies in the correspondence found between the type of interaction occurring in asynchronous computer conferencing and the phase of critical thinking. As presented above, synergistic threads showed more advanced phases of critical thinking on the Practical Inquiry Model of Cognitive Presence than instructor-centered threads. The connection between type of interaction and type and level of cognitive skill was suggested by Hara et al. (2000), who referred to the opportunities electronic collaboration tools offer for soliciting and sharing knowledge.

The correspondence between type of interaction and phase of critical inquiry reinforces claims of practitioners and previous researchers that asynchronous computer conferencing contributes to the learning process and that instructional approaches encouraging collaboration among learners are more effective than instructional approaches based on individual learning (Harasim, 1993; Hiltz, 1998). On a broader level, the findings fit social constructivist theories where thought is considered to be a socially mediated and dialogical process (Vygotsky, 1978; Wertsch, 1991, 1998) and where learning is seen to have a dialogical basis (Wells, 1996, 1999) involving distributed cognition. The findings are compatible with Perkins's (1993) concept of the "person-plus," described earlier, and underscore the importance of viewing the learner in the context of the entire "surround."

On the dimension of interaction, many of the patterns were similar to those found in past studies (Howell-Richardson & Mellar, 1996; Hara et al., 2000). However, despite many common trends and although

synergistic threads were identified in all three conferences in the present study, not all the interaction patterns found were present in all the conferences. Each conference showed features that differentiated it from the others and that could be explained by examining the combination of factors at work in the specific conference. For example, the distinctive spiral movement of cross-thread, or sustained, interaction characterizing Forum 1 was not apparent in Forums 2 and 3, probably as a result of two main factors. The first was the presence of active instructor moderation in Forum 1, compared to Forums 2 and 3. In Forum 1, following the initial questions and responses, which led to the first four discussion threads, the instructor posed questions that rephrased previous questions or related to responses in earlier threads, thereby deepening the dialogue. This characterized the instructor moderation throughout the conference. In Forums 2 and 3, deepening of the dialogue only occurred within the individual threads since the students became responsible for the discussion in specific threads, either as a result of the task specification (Forum 2) or as a result of the emergence of spontaneous student moderation (Forum 3). Although student moderation is to be encouraged, representing what Tagg (1994) calls student leadership from within, there was nothing to weave the threads together and each thread represented a mini-discussion of its own, similar to the patterns reported by Lipponen et al. (2003).

On the cognitive dimension, the findings on the whole suggest broad correspondences among the three measures of cognition, as shown in Table 2.

The correspondences below, together with the findings relating to the relationship between interaction and cognition, enabled the development of a scheme for assessing the quality of knowledge-building in

Table 2. Stages of cognition based on three models

Practical inquiry model	Bloom's taxonomy	SOLO taxonomy
Exploration	Comprehension	
	Application	Unistructural
	Preliminary analysis	Multistructural
Integration	Application	
	Analysis	Relational
	Preliminary synthesis	
Resolution	Synthesis	Relational
	Evaluation	Extended abstract

computer conferencing. The scheme, which uses the Practical Inquiry Model as its basis, is described in Schrire (2003).

Despite the similarities across the three conferences on the Practical Inquiry Model and the correspondences presented in Table 2, Forums 1 and 2 showed different patterns on the Bloom and SOLO taxonomies. (Messages in Forum 3 were analyzed only on the Practical Inquiry Model, so that Forum 3 is not relevant to the following part of the discussion.) It is possible that these two instruments, measuring individual cognition, are less suitable for measuring cognitive processes in collaborative learning settings. However, it is also possible to explain the discrepancies between Forums 1 and 2 if one compares the two conferences in terms of instructional task and average message length.

In Forum 1, the discussion centered around questions that required students to apply and analyze their own world experience and knowledge of ICT. Many messages were at the levels of *application* and *analysis*, as required by the task. This is compatible with Aviv's (2000) findings that the primary reasoning processes occurring in computer conferencing are related to those demanded by the instructional task. However, since the conference was characterized by a movement of deepening dialogue as described earlier, some of the messages went beyond *application* and *analysis* to the levels of *synthesis* and *evaluation*. Such messages were found mainly in the synergistic threads, which explains the statistically significant differences between thread types on Bloom's Taxonomy.

In Forum 2, the discussion question was of an analytical nature, grounded more in theory and research than in practice, so that the majority of messages were at the level of *analysis*, irrespective of thread interaction pattern. The Bloom Taxonomy was therefore less discriminatory in this conference than in Forum 1.

As far as SOLO measures were concerned, a large proportion of the messages in Forum 1 (62%) had a high degree of structural organization irrespective of the interaction pattern characterizing the thread they belonged to. Consequently, the SOLO Taxonomy did not discriminate between messages according to thread types in this conference.

In Forum 2, by contrast, structural complexity on the SOLO Taxonomy was differentiated according to thread type. The reason for the discriminatory capacity of SOLO in Forum 2 as opposed to its lack of discrimination in Forum 1 could be related to differences in message length between the two conferences. On average, the messages in Forum 2 were longer (mean number of words = 295, SD = 142) than those in Forum 1 (mean number of words = 181, SD = 108). Furthermore, simple ANOVA showed an inverse relationship between message length and interactivity in Forum 2, with messages in synergistic threads being

significantly shorter than the less interactive solo messages ($F = 5.18$, $p < 0.01$). Shorter messages may have more easily lent themselves to structuring and organization, possibly explaining the higher SOLO scores in the synergistic threads in Forum 2 and the uniform level of structural organization in messages in Forum 1. However, the connection between message length and interactivity may involve more than a simple inverse relationship and warrants further investigation.

To sum up the findings on cognition, although general correspondences were found among the three measures used, these are only tentatively proposed and need to be verified in future research. The findings central to the study, indicating a relationship between interaction and cognition, depend on how cognitive processes are operationally defined. The relationship was statistically significant in the two main case analyses when the Practical Inquiry Model was used but less clear-cut with the Bloom and SOLO taxonomies. Corroboration is therefore needed in future studies in similar and varied instructional contexts.

Recommendations

The findings from the reported study have specific implications for the practice of distance education and may have implications for face-to-face instruction, as well as for the development of constructivist theories of learning. Specific recommendations for future research are made below.

The correspondence found here between interaction and cognition merits further inquiry, both in additional instructional frameworks and on the basis of additional definitions and measures of cognition. It is important to take into account that the findings are based on an analysis of a limited number of cases, that the conferences were part of doctoral degree courses so that generalizability may be limited, and that inter-rater agreement in the coding of the cognitive dimension was only *fair* to *moderate*. Research examining additional cases that use computer conferencing as an instructional environment in similar and different subject domains would add to our understanding of the learning processes involved. Future studies should examine instructional conferences in elementary school, as well as secondary and tertiary educational settings in order to establish whether similar findings apply at different levels of learning and teaching.

The reported study revealed variations in interaction patterns in different conferences. Future research should aim at broadening knowledge of the range of interaction patterns possible in different contexts.

It was beyond the scope of this study to determine the direction of causality in the association between interaction and cognition. This question represents a possible avenue of investigation for future studies, which would best be conducted as causal-comparative research based on a quantitative paradigm. However, the present investigation suggests that this relationship is complex, so that experimental studies should be balanced by additional qualitative research that can provide a holistic understanding of how variables from the interactive and cognitive dimensions work together during the learning process.

Conclusions

The reported study represents a continuation of past research into the interactive and cognitive dimensions of computer conferencing. Basing itself on existing models for the assessment of the cognitive dimension of learning, the study examined the connection between interaction and cognition in three asynchronous computer conferences.

The characterization of conferencing interaction was similar to that done by Howell-Richardson and Mellar (1996) and Hara et al. (2000). Some of the patterns described by them were similarly represented in the three conferences mapped in the reported investigation. Additional patterns were found, and patterns common to all three studies were characterized on the basis of additional details. Although common trends may characterize different conferences, the interaction pattern mapping conducted in the present study suggests that each conference should be examined as a social unit with its own special character.

The quality of cognition was examined in all three conferences, which were found to be characterized by higher-order thinking. Statistical analysis of the cognitive dimension in the different thread types was performed in two of the conferences. The differences between synergistic interaction and other interaction types were significant in both conferences when the cognitive dimension of learning was operationally defined in terms of the Practical Inquiry Model. The third conference, which was only partially analyzed, showed similar trends. This finding has implications for both educational practice and theory construction since it suggests that collaborative processes in learning play an important role in knowledge-building. Recommendations were made for verifying the findings and determining their generalizability to a range of educational settings and using additional models for measuring the cognitive dimension.

Computer conferencing affords different opportunities for teaching and learning. Additional research is needed to increase understanding of the various ways in which computer conferences can be used to improve the knowledge-building process and promote higher-order thinking at all levels of the educational spectrum.

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