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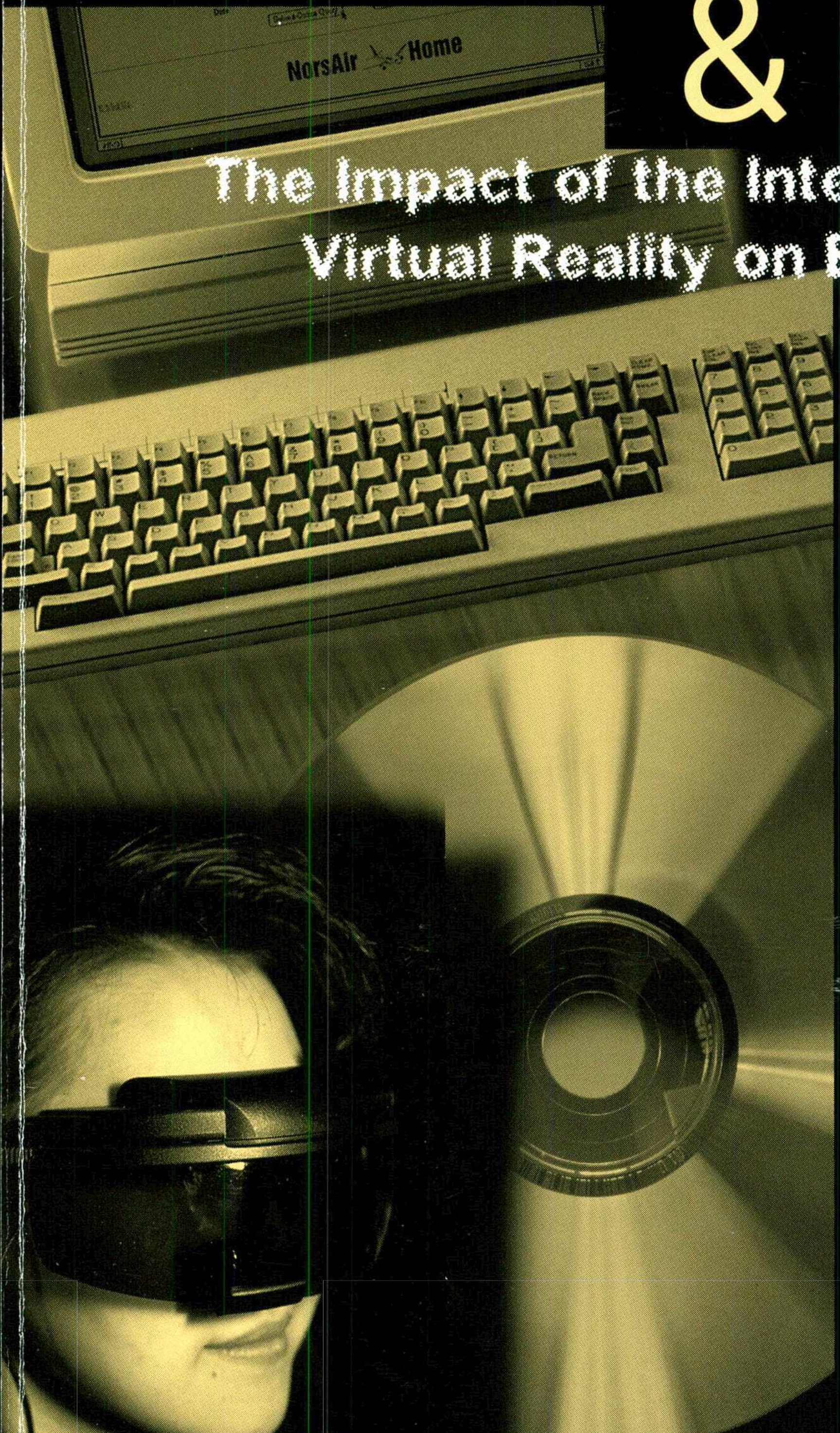

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In Search of Reflective Behavior and Shared Understanding in Ad Hoc Expert Teams

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ABSTRACT

The work reported on here concentrates on virtual ad hoc expert teams for the integration of learning and working, as ad hoc teams seem to be one way to cope with complexity in a knowledge-intensive society. In order to let ad hoc teams learn and work together, group members require effective communication and shared understanding among each other. Two empirical studies were conducted to study collaborative learning and shared understanding, one exploratory study and one experiment. In the first study, it was explored how virtual design teams work and learn together. Based on conceptual ideas, collaborative learning and shared understanding were observed and assessed in a design team over a period of four months. It was concluded that shared understanding was suboptimal; mainly due to the effect that hardly any questions were raised and answered. The second study elaborates on the need to encourage question-answer patterns and reflective behavior in such teams. A tool was developed that supported questioning behavior. As it was hypothesized that this tool leads to better questioning behavior, which in turn results in more reflective behavior and in increased shared understanding, an experiment was conducted. In the exploratory study, as well as in the experimental study, the perceived shared understanding increased over time. However, in both studies suboptimal questioning behavior and little reflective activity were noticed. The main results of the two empirical studies are compared and discussed.

INTRODUCTION

TODAY'S WORLD is becoming more and more complex and professional work is becoming more knowledge-intensive. At the same time, learning is more often integrated into the workplace.[1] In this way, people learn within the context of their work and thus require authentic experience in real-world problems. This work focuses on virtual ad hoc teams for the integration of learning and working, as ad hoc teams seem to be one way to cope with the complexity in knowledge-intensive society. In order to let ad hoc teams learn and work together, group members require effective communication and shared understanding among each other.[2] Like tango dancers who cannot start their dance without a certain amount of shared understanding, ad hoc teams cannot begin their work. The combination of distance and a strong reliance on technology makes understanding between virtual team members less

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than obvious. The research reported here concerns distributed design teams that need to be supported in their collaboration and communication processes. The goal is to enhance team potential by providing proper support. The underlying assumption is that proper support invites team members to learn and work together—similar to the right tango music that evokes the right mood and tempo for a certain moment. The research concentrates on collaborative learning and shared understanding in video-based communication and how it can be supported. In doing this, the following research questions are studied:

- How is shared understanding as an outcome of collaborative learning constructed?
- How can collaborative learning and shared understanding be assessed?
- How can the process of collaborative learning and reaching shared understanding in ad hoc design teams that work on collaborative design tasks using video-based communication be supported?

Conceptual framework: collaborative learning and shared understanding

Collaborative learning does not just mean that individual learning is enhanced by participation in small groups; it means that it is the groups themselves that learn. Knowledge is a product of such a collaboration process: it arises through interaction of different perspectives.[3] Collaborative learning takes place through processes of shared meaning-making.[4] Taking the learning perspective into account, the process of reaching shared understanding is viewed as an on-going collaborative learning process. Consequently shared understanding can be seen as an outcome of collaborative learning. As collaborative learning involves social or group processes on the one hand, and cognitive or individual processes on the other hand, this study includes aspects of both social and cognitive theories. The main concepts used for studying collaborative learning and shared understanding are: questioning, conceptual learning, feedback, and expression of affect.

Questioning is considered important by many researchers as it is seen as a way in which collaborators can check each other's intentions and understanding.[5–9] Mäkitalo and Häkkinen[8] conclude that feedback and questions offer team members evidence of each other's understanding. Questioning plays a central role in capturing miscommunication, and in preventing both cognitive and affective conflicts. Van der Meij and Boersma,[7] who coded e-mail communication, distinguished three kinds of speech acts: assertions, questions, and reactions. "Assertions" are statements of facts, principles, choices, etc., and whose main intent is to inform the other team members. "Questions," the second act of speech, are explicit requests for information, often signaled by a question mark. "Reactions," finally, are responses, and they include answers to questions and remarks on assertions. Following van der Meij and Boersma,[7] this triad is used here to get more insight in the team communication, assuming that the process of reaching shared understanding is suboptimal when assertions or questions were not followed by reactions.

Conceptual learning refers to the exchange of facts and concepts, reflection on them, and fine-tuning of them. The modes distinguished by Norman[10] have been adapted and redefined as follows. When concepts and facts are added, "accretion" occurs. "Tuning" refers to fine-tuning of these concepts and facts, that is, when utterances involve more specifics, more detail, or when utterances define more boundaries, or make the scope explicit. "Restructuring" was used when new relations between concepts or a new conceptual framework were created. "Co-construction" of knowledge[11] was added to Norman's troika. The main difference between the latter two modes of conceptual learning is that restructuring involves individual reflection, whereas co-construction concerns the restructuring by the whole team. To put it differently, co-construction involves the joint reflective action by the team. Compared to accretion and tuning, restructuring and co-construction require more iterations and interactions.

Feedback mechanisms are used to structure the communication process, and also to encourage reflection.[5] The use of feedback contributes to reaching shared understanding because listeners understand better when more feedback is provided.[12,13] Baker et al.[14] point out that feedback is necessary for reaching shared understanding. When things are going smoothly, this feedback can be just a simple acknowledgement. However, feedback can also take the form of repairs,[14] that is, to correct misunderstandings.[15] Moreover, some researchers view feedback as a specific type of learning.[16] Based on the functions of feedback in communication,[5] and to serve the specific goal here of measuring shared understanding, the following distinct feedback mechanisms are defined: "confirm," "paraphrase," "summarize," "explain," "reflect," "check understanding," and "check action." Inspired by the coding scheme of Anderson et al.,[17] the latter two variables "check understanding" and "check action" were added to the feedback mechanisms defined by Gramsbergen and Van der Molen.[5]

Learning is also a social endeavor.[18] Van der Meij et al.[19] use the concept of "affect" to assess motivation. In the research reported on here, the expression of affect was added to include motivational and evaluative expressions on the usefulness of acquired information. More specifically, the expression of certainty and uncertainty, and subjective expressions of the "value" of the situation are referred to. In addition, it is necessary to determine whether impasse was made explicit. "Impasse" occurs when team members express that they do not know how to go any further. An impasse can be seen as a moment of reflection.

To conclude, the concepts described here are based on the assumption that questioning, conceptual learning, feedback, and the expression of affect are central in the process of reaching shared understanding. Conceptual learning is associated more with cognition, whereas the expression of affect involves the motivational and emotional part of learning. Snow[20] labels this distinction as the cognitive and conative structures in learning. Finally, feedback relates to both questioning and learning, and focuses on the mechanisms that structure communication. Figure 1 presents the resulting conceptual framework on collaborative learning.

These conceptual ideas have been chosen as foci to better understand collaborative learning and the process of reaching understanding and, as a start, to develop instruments for assessing collaborative learning and shared understanding. In addition to the above concepts, this research makes the familiar distinction between task-related, social, process, and technology-related interaction.[5,21–23] Task-related interaction is about the content people are dealing with. Social communication concerns their relations to each other and personal information that is exchanged. Process interaction relates to planning and structuring the interaction, and technology-related communication is about the technology that supports the communication. The remainder of this article describes the setup and results of an exploratory and an experimental study. It concludes with a discussion of the comparisons between the two studies and on the relation of this work to similar work in the field.

EXPLORATORY STUDY: MATERIALS AND METHODS

The objective of this study was to follow a distributed ad hoc design team for a longer period of time, to see how the developed instruments were applicable and useful, and to find out to what extent the previously described conceptual framework was helpful in understanding collaborative learning and shared understanding.

Participants

A team of seven mechanical engineering students participated in the project during four months. These participants came from two different universities: one in the Netherlands and one in the United States, and did not know each other beforehand. The Dutch and American participants communicated in English.

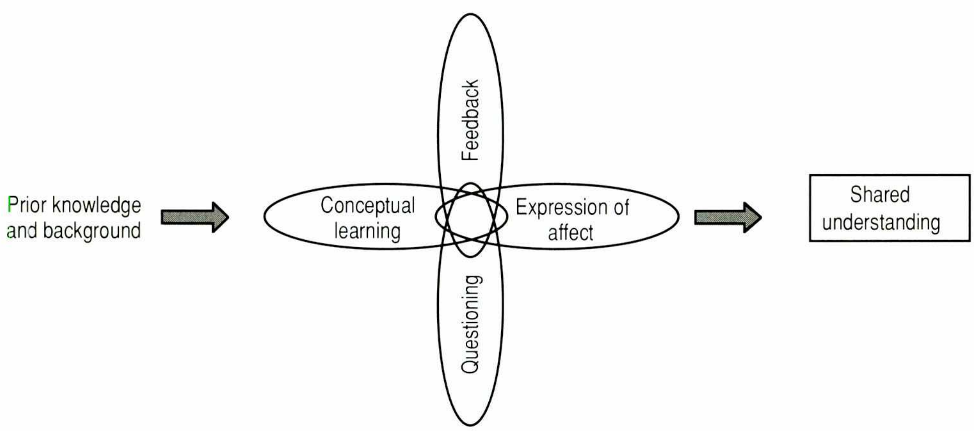

FIG. 1. Conceptual framework on collaborative learning.

Task

The collaborative design task given to this engineering team was to design a prototype to manually form the rear wheel well for a new car type. Participants received background information about the automotive industry partner. Furthermore, they needed to follow some assumptions and criteria in their engineering work as defined by the client. In other words, the participants were performing an authentic task, with a problem statement and basic constraints. The problem was ill-defined, and various ways of tackling the problem were available. They had four months to perform the task.

TABLE 1. OVERVIEW OF MEASURES AND INSTRUMENTS

Measures	*Instruments*
Team process	Interviews
Team process	Questionnaires
Team process	Observation
Participants experiences	Communication diaries
System usage	Log-files
Quality of final design	Expert rating (faculty)
Perception of shared understanding	Rating scale (self-score)
Collaborative learning and shared understanding	Analysis of transcripts using a coding scheme

Collaborative technology

In order to fulfill their collaborative design task, participants could make use of the following technology: (1) TeamSCOPE, a web-based collaboration tool which integrates several functions, such as sharing files, making comments, and sending messages. It also includes awareness tools, a calendar, and a chat function[24]; (2) ISDN desktop videoconferencing (Vtel™); (3) web-based desktop videoconferencing (NetMeeting™) which includes chat, and whiteboard functionality; (4) (hands free) telephone (i.e., point-to-point audio conferencing); (5) e-mail; and (6) fax. Participants were free to decide how often they met each other, which technology they used, and how to proceed and come up with the final result. It was not possible for the whole team to meet face-to-face, though each subteam had face-to-face contact. The set of collaborative technology allowed participants to work together at the same time (synchronous communication), as well as each individual team member to work on the engineering design task at a preferred moment (asynchronous communication).

Data collection

Several methods were used to gather both rich, qualitative and more numerical, quantitative data in all the design teams, namely observations, transcripts, interviews, questionnaires, weekly communication diaries, log-files of system usage, and expert judgment of performance,[25] as seen in Table 1.

An instrument (self-scoring rating scale) was developed to measure the perception of shared understanding.[26] This instrument measured how team members perceived their understanding concerning content, process, and relational aspects. The participants indicated how their understanding had evolved on 7-point rating scales (1 = shared understanding has decreased a lot, 4 = nothing has changed, 7 = shared understanding has increased a lot).

To get rich insights into the actual process of team communication, observation studies were performed. The team was observed during synchronous team communication (i.e., the video meetings) at both locations (semi-structured). The verbal communication during the ISDN desktop video meetings was recorded and fully transcribed. The main objective of these transcripts was to study the whole communication process in more detail. The transcripts were coded by means of a coding scheme, based on the conceptual framework described earlier. In order to calculate the reliability of our coding scheme, a random sample of 128 segments (of every other meeting) was coded independently by two experienced raters who had been instructed on the basis of the manual.[27] These 128 segments were coded for all categories. This represented 5% of the segments of the current study (i.e., 2531 segments). To calculate the inter-rater reliability—the equality of coding by the two raters—Cohen's coefficient kappa was used. This coefficient indicates the amount of agreement, corrected for the agreement expected by chance. The overall average value of the inter-rater reliability was 0.839, which is considered "almost perfect" by Landis and Koch.[28]

Coded transcripts gave insight in the question-answer patterns, and the amount and type of conceptual learning, feedback, and expression of affect. For the latter, the coded number of utterances was seen as indication for the amount of, for example, conceptual learning. Moreover, coded transcripts distinguished the extent to which communication was task-related, social, process-related or related to the technology used.

Another source of collected information was the expert judgment of the team's engineering work by engineering faculty.

RESULTS

This section reports findings regarding the role of questioning, conceptual learning, feedback, and the expression of affect in the process of reaching shared understanding. Also described are results on the average perceived shared understanding of the participants during the project. Table 2 displays how many assertions, questions, and reactions were coded in the transcripts. Table 3 shows the total number of task-related utterances, as well as how many of these utterances were dedicated to conceptual learning, to an expression of affect, and to feedback.

When assertions and questions are not followed by reactions, miscommunication is prone to occur. A relevant observation in this respect was a "miscommunication incident" in the third meeting. One sub-team had been raising questions on the problem statement for weeks. Nevertheless, they did not receive satisfactory answers from their remote team members. Examination of the coded transcripts revealed that these questions were not followed by reactions. After the awareness of the team members of the miscommunication during the first three weeks, the communication changed in favor of conceptual learning and feedback. Meeting 9, too, showed some evidence that questioning improved collaborative learning and shared understanding. In this meeting, the largest number of questions were raised (97), at the same time the most expressions of affect were uttered (57), and abundant feedback (127) was given. Meeting 4 only showed higher feedback rates. Although some evidence was found that questioning behavior improves collaborative learning and shared understanding, it can be concluded that communication was not optimal in the observed team. Compared to the number of assertions, and the number of questions, relatively few reactions to either the assertions or the questions were identified.

Another objective of the exploratory study was to investigate the roles of conceptual learning, feedback, and the expression of affect in the process of reaching shared understanding. Although the utterances devoted to conceptual learning, feedback, and affect did not increase, some evidence was found for the number of utterances devoted to conceptual learning, feedback, and the expression of affect supporting the process of reaching shared understanding. For example, when looking at communication related to the task, in Meeting 4 the largest number of utterances of conceptual learning were observed (100) and most feedback (133) was given compared to all other meetings. Also, the number of utterances devoted to affect was high (53). Only Meeting 9 showed a higher number (57 utterances). Table 4 compares the number of utterances devoted to conceptual learning and the expression of affect in task-related interaction between meetings 4 and 9.

An important observation was the overall lack of learning that required more iterations and more interaction, that is restructuring and co-construction.

TABLE 2. NUMBER OF UTTERANCES DEVOTED TO QUESTIONING BEHAVIOR PER MEETING

	Questioning (number of utterances)			*Meeting time (min)*
	Assertion	*Question*	*Reaction*	
Meeting 1	105	41	65	18:31
Meeting 2	106	54	99	25:50
Meeting 3	110	44	79	35:54
Meeting 4	186	42	69	31:23
Meeting 5	102	41	97	48:15
Meeting 6	70	37	42	29:11
Meeting 7	70	29	46	28:19
Meeting 8	79	28	46	26:17
Meeting 9	197	97	100	48:29
Meeting 10	118	34	48	22:08
Meeting 11	80	32	46	16:43
Total	1223	479	737	5:31:00

TABLE 3. NUMBER OF TASK-RELATED UTTERANCES DEVOTED TO CONCEPTUAL LEARNING, AFFECT, AND FEEDBACK

	Number of task-related utterances			*Total task-related utterances*
	Conceptual learning	*Expression of affect*	*Feedback*	
Meeting 1	38	30	31	121
Meeting 2	47	40	85	150
Meeting 3	49	33	69	176
Meeting 4	100	53	133	232
Meeting 5	19	17	33	87
Meeting 6	23	18	39	63
Meeting 7	37	33	60	115
Meeting 8	8	26	37	77
Meeting 9	34	57	127	197
Meeting 10	15	36	62	119
Meeting 11	1	14	30	62
Total	371	357	706	1399

In other words, the most common types of conceptual learning observed were accretion and tuning, especially in the beginning of the project. Interestingly, the highest amount of conceptual learning occurred in the fourth meeting, that is 100 utterances (49 accretion, 45 tuning, and 6 restructuring). This was the first meeting after participants had solved a big misunderstanding and had reframed their problem statement (i.e., the miscommunication incident in Meeting 3). Also, in the weekly diaries the participants stated that their remote team members understood more about the project. Participants indicated the highest ranking on shared understanding of the content on the rating scales. These observations seem to indicate that conceptual learning and shared understanding are related positively. These results seem to support the idea that a certain amount of shared understanding—in this case, enough shared understanding on the problem formulation—is necessary in order to learn.

TABLE 4. COMPARISON BETWEEN MEETINGS 4 AND 9 CONCERNING TYPES OF CONCEPTUAL LEARNING AND EXPRESSION OF AFFECT IN TASK-RELATED INTERACTION

	Meeting 4	*Meeting 9*
Conceptual learning		
Accretion	49	21
Tuning	45	10
Restructuring	6	3
Co-construction of knowledge	0	0
Total	100	34
Expression of affect		
Evaluation	34	37
Uncertainty	17	19
Impasse	2	1
Total	53	57

It was found that during their second meeting the participants devoted the most utterances to conceptual learning, feedback, and affect related to social aspects. After this meeting they all agreed that they felt they knew the other team members better (rating scales). After the first meeting the participants also devoted more time to social interaction (raw transcripts). Again, there seems to be evidence that a certain amount of shared understanding is necessary in order to learn and update shared understanding. A more detailed look into the categories of conceptual learning showed that conceptual learning was constrained to accretion and tuning, and restructuring and co-construction hardly took place. Analyzing types of feedback, it was found that reflection was underrepresented. Finally with respect to expression of affect, "impasse" hardly occurred. This leads to the conclusion that communication related to reflective behavior was underrepresented. This observation is to be elaborated in the discussion section.

As shared understanding was viewed as a result of collaborative learning, perceived shared understanding should increase in the course of a project, at least if the team learns. Rating scales to measure the perception of shared understanding were used and applied at the end of meetings 2, 3, 4, 5, and 10. Participants were asked to indicate their perception of shared understanding on a 7-point scale (1 = shared understanding has decreased a lot, 4 = nothing has changed, 7 = shared understanding has increased a lot). With respect to the question "Since the previous meeting, to what extent do you feel a common understanding of the project (in general terms) has emerged?" the average perceived understanding was indicated with a 5 after meeting 2, 3, 4, and 5, and a score of 5.5 was indicated after meeting 10. Analysis of the results of the rating scales indicates that the amount of perceived shared understanding increased during the project.

The participants' final result was considered successful by their faculties, and the client firm was satisfied as well. The successful completion of the project can be regarded as evidence for collaborative learning having taken place.

CONCLUSION

By exploring video-based communication processes in a distributed design project, insight was gained into collaborative learning and shared understanding. The average perceived shared understanding of the team members appeared to increase. Some rough evidence was found that questioning, some types of conceptual learning, feedback, and the expression of affect have a positive impact on the process of reaching shared understanding. In addition, hardly any questions were raised and answered. Moreover, very little reflective behavior in their learning modes, in their feedback, or in their expression of affect was exhibited. To conclude, the current study indicated suboptimal question-answer and reflective behavior. Also, some evidence appeared to exist that the questioning and answering process and reflective behavior are related. Although the evidence was based on a single study with one team, the main intent was to tackle the problem of better understanding collaborative learning and shared understanding by assessing collaborative learning and shared understanding in an empirical study. The second part of this study will elaborate upon the need to encourage reflective behavior in virtual teams.

EXPERIMENTAL STUDY: MATERIALS AND METHODS

The second part of the study concentrates on how team members pose questions and receive answers. For this question-answer behavior, a specific tool was developed. Taking into account the social and cognitive functions of questioning processes, three prototypes that supported questioning and answering process were developed. These were evaluated in a user pilot, which resulted in a final Q-tool.[29] As it was hypothesized that this tool leads to more or better questioning behavior, which in turn results in more reflective behavior and in increased shared understanding, an experiment was conducted to test these hypotheses.

In a quasi-experimental study, there were two main questions: is the Q-tool strong enough to encourage questioning behavior, and does this intervention lead to improved collaborative learning (i.e., more reflection) and shared understanding? The experimental setting was made as realistic as possible: participants (university students) worked on a complex design task, in two sub-teams, using collaborative technology. The "unrealistic" part was that teams were not really geographically dispersed, but carried out their design tasks in two separate rooms within the same building. The independent variable was the presence or absence of the Q-tool. The dependent variables were several concepts of collaborative learning and shared understanding. It was hypothesized that teams with a Q-tool learn more and understand each other better than teams without a Q-tool. The Q-tool supports the question-answer process in the teams, and therefore, teams with a Q-tool have optimal questioning and answering patterns, which results in more reflection. Consequently, teams with a Q-tool learn and understand more. Other assumptions are that shared understanding increases over time, and that increased shared understanding leads to better team performance and higher product quality. In the remainder of this section, the experimental setup and the technology used are explained. After that, results of the experimental study are displayed.

Participants

Participants in the current study were 20 teams of four to seven participants ($N = 20$, $n = 110$), who were recruited from three universities in the Netherlands. Participants with differences in study background, nationality, age, and motivation for participation (voluntarily or part of the curriculum) were distributed as equally as possible across teams with and without a Q-tool to achieve comparable team composition.

Task

The participants had to perform a collaborative design task during one and a half hours. This design task involved the creation of an added value service for a university portal.

Collaborative technology

All teams had audio and videoconferencing tools available. The teams were provided with a laptop with desktop videoconferencing (Microsoft NetMeeting™), which included chat, shared whiteboard, and file and application sharing functionality. The laptops were connected with a wireless LAN at 11 Mb/sec. For the video, two Philips ToUcam USB cameras were used. Ten teams had the Q-tool available in addition to audio and videoconferencing tools. Both sub-teams have the button "Question" next to the video screen. By clicking on this button one expresses the desire for questioning, and a red question mark appears on the video screen of the remote team. Only the sub-team that presses the button can remove the question mark by clicking "We've got an answer."

The other 10 teams could only communicate by means of audio and videoconferencing. In order to avoid an audio bottleneck the teams were provided with (two-way) half-duplex hands free telephones. Teams also had common visualization tools at hand: paper, pencils, flip chart, and white board. Figure 2 shows the experimental setting as seen on both laptops during the teamwork. The three participants in the right-hand frame just pressed the Q-button to get attention of their remote team members. Therefore, the three participants in the left-hand frame see a question mark on top of their screen (Fig. 2).

Data collection

Several instruments were used to collect data to assess aspects of collaborative learning and shared understanding, such as the perception of shared understanding (both process and product), quality of final result, and quality of the team communication. Table 5 displays the measures and instruments used to get more insight in these aspects of collaborative learning and shared understanding.

Perception of shared understanding

For the assessment of the perception of shared understanding, the same rating scales as in the exploratory study were used. In addition, perceived shared understanding of the final portal design (product) was also assessed. For this aspect, each participant was asked to describe, in their own words, the features of the final design their team came up with. All descriptions were collected. Two experts judged these individual descriptions, using a six-point scale (1 = not at all corresponding, 6 = completely corresponding) to indicate the extent to which the descriptions of a whole team were consistent. Just after participants finished their description, one description was randomly selected and read aloud. All team members indicated to what extent the description read aloud corresponded with their perception of the final design. They indicated on the same six-point scale the extent to which the description corresponded with their own description, and indicated on a second scale to what extent the description corresponded with their idea of the final result. Then, a second

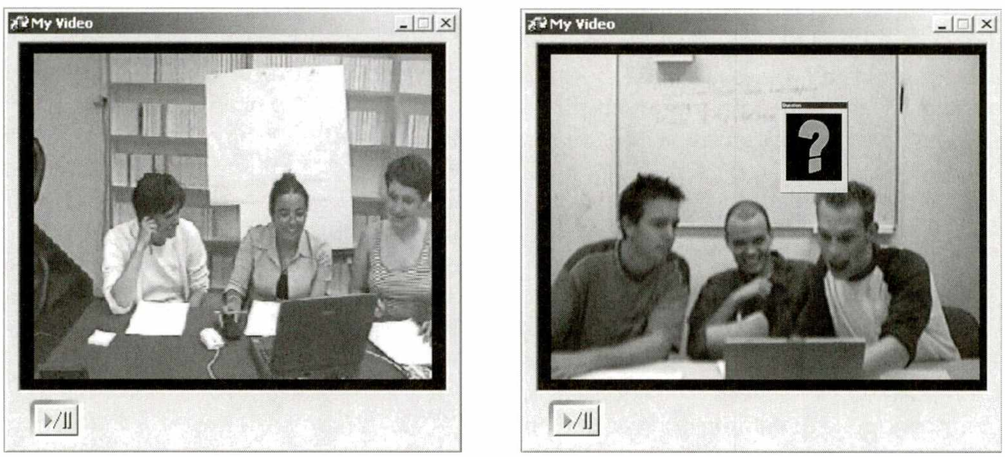

FIG. 2. Experimental setting. Both sub-teams are working on their design task.

TABLE 5. OVERVIEW OF MEASURES AND INSTRUMENTS USED IN THE EXPERIMENTAL STUDY

Measures	*Instruments*
Perception of shared understanding	Rating scale (self-score)
Perception of shared understanding of final design	Rating scale (self-score and expert rating)
Team communication process	Video-analysis coding scheme
Participants experiences	Report
Prior knowledge and experience	Questionnaire
Quality of final design	Expert rating
Facilitating behavior	Observation scheme
Use of Q-tool	Log-files

description was read aloud and one team member was asked to explain in his or her own words what (s)he thought the writer meant. Finally, the "description writer" indicated on the same six-point scale the extent to which the explanation corresponded with his or her description. These five scores of the perception of shared understanding of the final product are respectively referred to as "Description—expert 1," "Description—expert 2," "Description—self-score," "Idea—self-score," and "Explanation—other."

Team communication

A coding scheme was developed for analyzing the observed team communication. This scheme is an adapted version of the one used in the exploratory study.[30] Additionally, other measures to get more insight in the teams were used: a pre-questionnaire looked up differences in background, participants were asked to reflect on their experiences afterward, and the communication process was observed and videotaped.

Quality of final design

To get insight into the relationship between collaborative learning and shared understanding and the final result of the teamwork, the quality of the final portal design was measured. Experts judged the quality of the final designs using a five-point scale (++, +, 0, −, −−). The quality of the portals was assessed based on the eight criteria mentioned in the task description. Finally, all plusses and minuses lead to a sum score. The sum scores were ranked.

Use of Q-tool

The experimental setup generated log-files of the Q-tool to monitor its usage (frequency), including information on the sub-team pressing the Q-button, and at what time.

RESULTS

In this section the results for teams with and without a Q-tool are displayed.

Perception of shared understanding

The numbers in Table 6 increase from T0 to T3; this indicates that the perception of shared understanding increased in the experimental group (with Q-tool) as well as in the control group (without Q-tool).

A Friedman test pointed out that shared understanding significantly increased across the 20 teams ($\chi = 38.638$, $df = 3$, $p < 0.001$). When looking at this increase across teams with a Q-tool, shared

TABLE 6. PERCEPTION OF SHARED UNDERSTANDING AT START (T0) AND AFTER EACH HALF HOUR (T1, T2, T3) IN TEAMS WITH AND WITHOUT A Q-TOOL (MEAN AND [SD])

Q-tool	*T0 mean*	*(SD)*	*T1 mean*	*(SD)*	*T2 mean*	*(SD)*	*T3 mean*	*(SD)*
With ($n = 10$)	3.48	(0.52)	4.02	(0.33)	4.37	(0.34)	4.71	(0.36)
Without ($n = 10$)	3.40	(0.59)	3.98	(0.48)	4.05	(0.42)	4.39	(0.40)

TABLE 7. PERCEPTION OF SHARED UNDERSTANDING OF FINAL DESIGN IN TEAMS WITH AND WITHOUT A Q-TOOL (MEAN AND [SD])

Q-tool	*Description (expert 1)*	*Description (expert 2)*	*Description (self-score)*	*Idea (self-score)*	*Explanation (other)*
With (n = 10)	4.05 (1.03)	3.84 (0.85)	4.47 (1.14)	4.97 (0.92)	5.30
Without (n = 10)	4.68 (0.77)	4.50 (0.70)	4.71 (1.08)	4.92 (0.97)	5.50

understanding increased significantly (χ = 16.212, df = 3, $p < 0.001$). However, teams working without a Q-tool also had a significant increase in shared understanding (χ = 23.520, df = 3, $p < 0.001$). A Mann-Whitney test on the effect of the Q-tool found no significant differences on the increase of shared understanding between conditions ($Z < 0$, $p > 0.10$).

Perception of shared understanding of final design

The perception of shared understanding of the final design using participants' descriptions was measured with both expert rating and self-scores. Two experts rated independently all the individual descriptions. The Pearson correlation coefficient of the experts' scores was 0.74 ($p < 0.01$), which implies their ratings corresponded substantially. Also scores of "Description—expert 1" and "Description—self-score" correlated significantly ($p < 0.05$), "Description—expert 2" and the self-scores on description did not correlate significantly ($p = 0.069$. Table 7 shows the results of the perception of shared understanding of the final design (1 = not at all corresponding, 6 = completely corresponding). Almost all scores are higher than 4. The scores with respect to "Idea—self-score" show that teams with a Q-tool had higher perceived shared understanding of the final design than teams without. These scores confirmed the hypotheses. A Mann-Whitney test on the measures of shared understanding of the final design showed no significant differences between experimental conditions for "Description—self-score," "Description—expert 1," "Idea—self-score," and "Explanation—other" ($Z < 0$, $p > 0.1$). Only the scores of "Description—expert 2," differed significantly between conditions ($Z = -2.121$, $p = 0.034$). This result was contrary to the expectation that shared understanding would be higher in teams with a Q-tool.

Team communication

Results from the video analyses (Table 8) reveal many content proposals in all teams, and relatively few process proposals. It seemed that communication was focused on the content, and apparently involved utterances that can be interpreted as "answers." In relation to the number of content proposals, few questions were raised. High scores on "confirm" seemed to indicate that team members did listen to each other. No collaborative reflection was found in any of the teams. The averages indicate that there were few impasses expressed in all the teams. The Mann-Whitney test did not obtain any significant differences ($Z < 0$,

TABLE 8. RESULTS OF THE CODED VIDEOS IN TEAMS WITH AND WITHOUT A Q-TOOL (MEAN AND [SD])

Q-tool	*New question*	*More questions*	*Content proposal*	*Process proposal*	*(Dis)confirm*
With (n = 10)	65.60 (14.26)	30.30 (9.63)	106.50 (32.24)	28.10 (12.52)	206.20 (64.05)
Without (n = 10)	78.70 (13.84)	36.20 (10.82)	119.80 (22.67)	31.70 (5.27)	194.30 (64.44)

Q-tool	*Feedback*	*Reflection*	*Impasse*	*Collaborative reflection*
With (n = 10)	81.00 (20.29)	3.60 (3.66)	0.30 (0.67)	0 (0)
Without (n = 10)	100.50 (45.10)	5.80 (3.99)	0.40 (0.70)	0 (0)

$p > 0.10$) on team communication processes between experimental conditions.

Quality of final design

Two experts on portal design judged the final designs. A Mann-Whitney test was performed to identify differences between experimental conditions in the quality of the final portal design. The final designs produced by teams with and without a Q-tool do not show significant difference in quality ($Z < 0$, $p = 0.76$).

Use of Q-tool

The average use of the tool was 30.9 times. In the participants' experiences, the team that used the tool most (73 times) wrote that they experienced the Q-tool as a good way to get attention of the remote sub-team. However, the team that used the tool 51 times indicated that they used the tool primarily for fun. These frequencies do not allow for unambiguous interpretation.

CONCLUSION

The current study offered insight into learning and understanding in distributed teams by focusing on their questioning behavior. It was hypothesized that teams with the Q-tool have a better questioning and answer behavior, subsequently reflect more, learn more and have a higher shared understanding than teams without. Results of the assessment of the perception of shared understanding confirmed the hypotheses to some extent. Though not significantly different, teams with a Q-tool indicated a higher perceived shared understanding than teams without a Q-tool. Teams with questioning support did not significantly perform better question-answer behavior or reflective behavior, nor was the quality of resulting designs rated differently for the two groups.

DISCUSSION

In the exploratory study as well as in the experimental study, the perceived shared understanding increased over time. However, in both studies suboptimal questioning behavior and limited reflective activity was observed. In the following sections, some of the main results of the two empirical studies are compared. Finally, the findings of the current study are compared with related research investigating reflective behavior in technology-mediated settings.

Quality of team communication

Table 9 shows the main figures regarding the quality of the team communication processes. All data displayed are averages per 90 min. Although no hard proof can be found, these comparisons indicate some differences and similarities.

TABLE 9. FIGURES REGARDING THE QUALITY OF TEAM COMMUNICATION PROCESSES IN BOTH STUDIES (CODES USED IN EXPLORATORY STUDY VS. EXPERIMENTAL STUDY)

		Experimental study	
	Exploratory study (n = 1)	*Without Q-tool (n = 10)*	*With Q-tool (n = 10)*
Questions (Questions vs. new and more questions)	130.6	114.9	95.9
Question–answer pairs (reactions vs. feedback and confirm)	201.0	294.8	287.2
Feedback (feedback vs. feedback and confirm)	274.9	294.8	287.2
Reflective behavior (reflect, restructuring, and evaluation vs. reflection and feedback)	104.5	106.3	84.6
Reflection (reflect vs. reflection)	11.5	5.8	3.6
Collaborative reflection (co-construction vs. collaborative reflection)	0	0	0
Impasse (impasse vs. impasse)	3.8	0.4	0.3

With regard to "reflection" and "impasse," there are differences "in favor" of the exploratory study. However, the questioning and answering process seems to be better developed in the experimental study. "Collaborative reflection" was not found at all in either study. Another remarkable finding is that the least reflective behavior occurred in the teams with a Q-tool. This is contrary to our expectations. A final observation is that the precise way of coding the utterances matters: when coded strictly, hardly any reflection takes place in the two studies (i.e., from 3.6 to 11.5 times in 90 min). With less stringent coding the amount of utterances related to reflective behavior is substantial (i.e., from 84.6 to 106.3 times in 90 min). The main reason to adapt the coding scheme from the first to the second study, was to simplify the coding process and to focus on higher order reflective behavior—for example, facts and remarks that were coded in the first study as assertions or accretion were not taken into account in the experimental study. More specifically, in the second study only "feedback to questions" has been coded or "short confirms to questions" that indicated that the question had been understood. In the first study *all* reactions to questions were coded in calculating question-answer pairs. Taken into account this adjustment in favor of higher order reflective behavior not only were more question-answer pairs found in the experimental study, these pairs could also be viewed as a higher quality of communication. Nevertheless, the experimental condition did not show more question-answer pairs than the control group.

It can be concluded that subtle adaptations in definitions and related operationalizations of reflective behavior can lead to substantial differences in results of the studies. Moreover, it appeared not at all easy to improve (change and predict the results of) reflective behavior. Furthermore, it was difficult to define a relationship between question and answer patterns and reflective behavior as questioning does not always lead to more reflection. An interesting question to study in more detail is whether any kind of questioning can be perceived as useful in terms of learning and reflection. In addition, more insight into what kind of questions are particularly difficult to express in virtual teams seems to be relevant. In the first study, a lot of utterances were coded as accretion and tuning; it seems that sharing facts and fact-seeking questions are not that difficult in virtual teams. It can be assumed that making inquiry questions that would seek deeper explanations for the phenomena under study is more difficult, but would be more beneficial in terms of learning than making fact-seeking questions. The main reason for using a coding scheme was to look more at the quality and nature of questioning. Next to counting questions, it was possible to code whether such utterances involved aspects of learning and reflection, though we did not distinguish whether one question would trigger more reflection or was of better quality than another one. It would be interesting to elaborate on the distinctive roles of questioning in virtual teams in future work; for example, what kind of questions do lead to reflective behavior and which questions do not.

Final observations

Most research on reflective behavior in technology-based settings concentrated on text-based environments,[6,14,31–34] far less research studied video-based communication. Despite the growing application of video-conferencing in learning and working settings, little is known about possibilities of enhancing collaboration in video-based communication. Additionally, only few studies in the field of videoconferencing focused on processes and outcomes in the context of learning.[35] A more detailed look at studies in the field of videoconferencing lead to the conclusion that most research on video-based communication focused either on the design and use of video-based communication or on the comparison with face-to-face communication. Hardly any empirical studies on video-based communication showed results with respect to the quality of collaborative learning and shared understanding. Similarly, Fischer and Mandl[36] concluded that no systematic studies have been conducted with respect to process and outcome measures of collaborative learning.

A final distinction is that most studies on reflective behavior take place in educational settings, and hardly in organizational or business settings.[37] Although learning and working are more and more integrated in practice, such integration is not yet visible in research.[38]

In sum, few studies have been conducted on collaborative learning and shared understanding in video-based communication. At the same time, research that concentrated on reflective behavior in technology-supported teams showed disappointing results. One possible explanation for the poor evidence for reflection is that such behavior just did not occur in those studies. Expectations might be too high: performing genuine reflective behavior appears to be very difficult. In that case it is a challenge to better understand reflection and to investigate which incentives can stimulate a team's reflective behavior. Another explanation is that current researchers, including the authors of this work, were not able to apply an appropriate (for example, too rigid) coding procedure for (collaborative) reflection. It follows that reconsidering data collection methods on collaborative learning, shared understanding, and reflective behavior (and related concepts) is a major research challenge.[39] The objective of the current work was twofold. This study aimed at better understanding and stimulating collaborative learning and shared understanding, as well as developing methods for assessing both collaborative learning and shared understanding processes and outcomes. To conclude, this work might inspire others to continue this line of research. There is a lot to gain in supporting ad hoc distributed teams dealing with the complexity of today's world.

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