Designing Electronic Collaborative Learning Environments

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Electronic collaborative learning environments for learning and working are in vogue. Designers design them according to their own constructivist interpretations of what collaborative learning is and what it should achieve. Educators employ them with different educational approaches and in diverse situations to achieve different ends. Students use them, sometimes very enthusiastically, but often in a perfunctory way. Finally, researchers study them and—as is usually the case when apples and oranges are compared—find no conclusive evidence as to whether or not they work, where they do or do not work, when they do or do not work and, most importantly, why they do or do not work. This contribution presents an affordance framework for such collaborative learning environments; an interaction design procedure for designing, developing, and implementing them; and an educational affordance approach to the use of tasks in those environments. It also presents the results of three projects dealing with these three issues.

☐ Current research on and design of collaborative learning environments—often referred to as computer supported collaborative learning (CSCL) environments—tends to focus on surface-level characteristics. Educational researchers and designers are busy, for example, determining optimal group size for problem-based education as opposed to project-centered learning. To determine optimal group size, students' collaborative efforts and the results of these efforts are compared for groups of varying size in different educational settings. This approach resembles comparative research on the use of different media in education that was strongly—and we had hoped definitively—criticized by both Clark (1983) and Reeves (1993). Such research focuses on the media used and surface characteristics of the education provided. This surface-level approach disavows the fundamental differences between the real determinants of learning and behavior in education and results in learning materials that are unreliable or even mathemathantic.

A second problem is that educational institutions tend to apply traditional classroom ideas and pedagogy in noncontiguous collaborative learning environments, assuming that because these environments allow the interaction that we see in the classroom (e.g., chat, real-time meetings, and shared applications) traditional pedagogy can be used. Unfortunately these environments do not support such interactions

in the same way that it occurs in face-to-face (i.e., time delay, lack of complete sensory contact, nonavailability of off-task activities, etc.). The proximate result is often disgruntled or disappointed students and instructors, motivation that is quickly extinguished, poorly used environments, wasted time and money, and showcase environments that are often not much more than computer assisted page turning. The ultimate result is very similar to the first problem—no learning, because the students tend to give up.

The solution is as simple as it is elegant, namely attending not only to the technological prerequisites for collaboration (i.e., the technological environment), but also to the educational and social prerequisites for allowing collaboration to occur (i.e., the pedagogy and the social dynamics, respectively). The educational part would take care of the first problem: choosing the right pedagogy to achieve one's aims, which takes the characteristics of the media into account. The social part would enrich the chosen pedagogy by adding those elements usually almost automatically existent in contiguous learning, group formation and social dynamics within the group. This article provides a framework for designing such collaborative environments based upon the three prerequisites, (a) technological, (b) educational, and (c) social. It then goes into somewhat greater depth with respect to three nonsurface-level educational factors central to collaboration, (a) task ownership, (b) task character, and (c) task control. Finally conclusions are presented.

What follows is a discussion of three major issues of this article, (a) the role of three different types of affordances in stimulating and maintaining collaboration in primarily asynchronous distributed group learning (with emphasis on social affordances for group awareness), (b) interaction design and its use and power in designing and developing technologically well afforded electronic learning environments for collaborative learning, and (c) the role of tasks in educationally affording collaboration in asynchronous distributed groups. The article concludes with a description and the results of three projects dedicated to studying these three issues.

AFFORDING COLLABORATION

Traditional instructional design is based on insights from cognitive psychology (Kirschner, Van Merrienboer, Carr, & Sloep, 2002) and, as such, is fairly deterministic or *causal* in that it tends to focus on individual learning outcomes by influencing or controlling instructional variables to create a learning environment that supports the acquisition of a specific skill (a certain person will acquire a specific skill through the implementation of a chosen learning method). Collaboration complicates using this approach. Here, individual and group-level variables mediate the learning process such that it is nearly impossible to predefine conditions of learning or instruction to control interaction and skill acquisition.
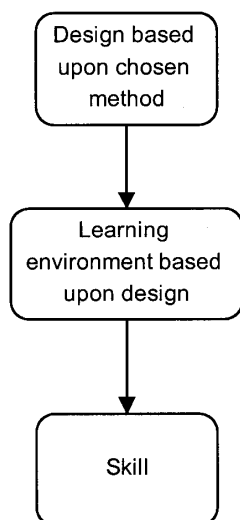
Instead of a classic causal view, design of collaborative settings, because of the possible unforeseen interactions between group members, requires a more probabilistic or systemic view on design. This distinction is to a large extent similar to Van Merriënboer and Kirschner (2001) who distinguished between the world of knowledge (outcome) and the world of learning (process). In the world of knowledge, designers construct methods by which given learning goals in a specific subject matter domain can be attained by the learner. In the world of learning, designers focus on methods supporting learning processes, and not attainment of predefined goals (see Figure 1 from Strijbos, Martens, & Jochems, 2004).

This probabilistic view is similar to the systemic view (Merrill, 2002; Reigeluth, 1999; Van Merriënboer, 1997), except in the way that they handle complex interdependencies. In the systemic view complex interdependencies are specified in advance, whereas in the probabilistic view they are treated as unknowns and are not specified. A probabilistic design view—as opposed to a systemic design view—is more suited to collaborative environments because of the large number of individual group member characteristics that may emerge (emergent properties) and affect interaction. These characteristics are difficult to specify, making it almost impossible to specify their interdependencies.
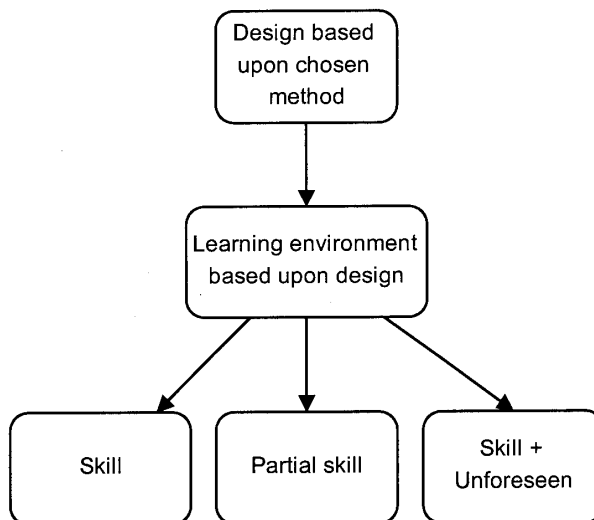
This probabilistic view implies that more

Figure 1 □ Two views on instructional design (Strijbos, Martens, & Jochems, 2004).

Causal design view:
World of knowledge

Probabilistic design view:
World of learning

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Design based          Design based
upon chosen           upon chosen
method                method

Learning              Learning environment
environment based     based upon design
upon design

Skill            Skill    Partial skill    Skill +
                                           Unforeseen
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attention be paid to learning and interaction processes. Because of the interactions between learners, each person in a group may acquire a given skill through the chosen method, but may equally likely acquire only a part of the skill, or the skill plus something unforeseen. It might even be the case that the chosen method is abandoned by the group and replaced by another, more idiosyncratic method for that group. The question is not what outcomes specific educational techniques and collaborative work forms cause, but rather what activities they actually afford, also often referred to as the *affordances* of a learning environment. Specific types of learning need to be afforded in different ways (i.e., different opportunities provided for learning) because the learners perceive and interact with each other and with the environment differently.

What are affordances? They are opportunities for action; the perceived and actual fundamental properties of a thing that determine how the thing could possibly be used (Norman, 1988, p. 9). Affordances are most visible in real life. Some door handles, for example, look as if they should be pulled. Their shape leads us to believe

that this is the best way to use them. Other handles look as if they should be pushed, a feature often indicated by a bar spanning the width of the door, or even a flat plate affixed to the side. Gibson (1977) originally proposed the concept of affordances to refer to the relationship between the physical properties of an object and the characteristics of an actor (user) that enables particular interactions between actor and object. "The affordance of anything is a specific combination of the properties of its substance and its surfaces with reference to an animal" (p. 67). These properties and surfaces interact with potential users and provide strong clues as to their operation.

An affordance is, by definition, characterized by two relationships. First, there must be a reciprocal relationship between the organism and the environment. For example, a fallen tree must have a certain size (i.e., it cannot be as large as a sequoia) and a person must have flexible knee and hip joints (unlike those of a giraffe, which fold in the opposite direction) for the person to be able to sit on a log. The affordances must be perceivable and meaningful so that they can be used and must support or anticipate an action. Second, there must be a perception-action cou-

pling. Once the need to do something (i.e., we get tired while walking in a forest) becomes salient (i.e., we perceive the fallen tree as a place where we can sit), the sit-affordance will not only invite but will also guide us to make use of the tree trunk to satisfy that need (action). The salience of the intervention may depend on factors such as expectations, prior experiences, and/or focus of attention. In Gibson's (1977) view, natural selection has tuned a species' effectivities to the affordances associated with its niche or occupation (Allen & Otto, 1996). In Gibson's terms, effectivities (i.e., one's capabilities for action) allow humans to exploit their world just as effectivities such as wings allow birds to exploit the air for travel and the branches of trees for nesting. In our view, the concept of affordances offers an alternative framework for designing and evaluating collaborative learning environments if appropriated to the educational context.

Education is always a unique combination of technological, social, and educational contexts and affordances. Classical educational contexts, for example, are often competitive (educational) and individual (social), with students working at their own place on their own (physical and technical). Group learning, on the other hand, makes use of collaborative or cooperative pedagogies (educational), in groups (social), and provides a group workspace with the necessary assortment of materials (physical and technical). CSCL represents yet another learning situation. The educational context is collaborative, the social context is the group, and the technological context is a computer-mediated setting. The Open University of the Netherlands, for example, uses a computer-mediated communication environment (technological) for competency-based learning grounded in social constructivism (educational) with minimal direct contact, maximal guided individual study, and primarily asynchronous, text-based contact between students (social).

When technology mediates the social and educational contexts such that their properties induce and invite specific learning behaviors, we speak of technology affording learning and education.

Technological Affordances

Norman (1988) linked affordances to an object's usability, and thus these affordances are designated technological or technology affordances (Gaver, 1991). Usability is a well-known objective of industrial or product design dealing with physical objects ranging from video-recorders to teapots, and human-computer interaction dealing predominantly with graphical user interfaces composed of interface objects such as buttons and scrollbars. Usability is concerned with whether a system allows for the accomplishment of a set of tasks in an efficient and effective way that satisfies the user (e.g., Preece et al., 1994). Neglecting usability criteria risks creating CSCL environments that contain all the needed educational and social functionalities (in Nielsen's 1994 terminology *utility*), but that cannot be handled by their users (i.e., the learners) because they are difficult to learn, access, and/or control. This is exemplified by Norman (1992) who maintained that the major problem with most new technological devices and programs—and in our opinion also in their use in education—"is that they are badly conceived, developed solely with the goal of using technology. They ignore completely the human side, the needs and the abilities of people who will presumably use the devices" (p. 65). An example of this is the escalator, a moving stairway that was designed to speed human traffic in a stairway by increasing a person's stair climbing speed with the speed of the moving stairs. As we all have probably experienced, it has actually achieved the opposite! Large crowds tend to gather and cue at the top or bottom of the escalator because people tend to stand still on the escalator itself. This could be the result of human nature that was not entered into the design equation (i.e., inherent laziness), the nonergonomic step size that is found on almost all escalators (e.g., climbing or descending an escalator that is out of order is uncomfortable because of the tread vs. riser ratio) or a combination of the two. Good design means taking the usability aspect into account, and thus requires a design process grounded in user-centered design research.

Later in this article we will discuss the fact that usability is a necessary although not suffi-

cient factor when designing, developing, and researching CSCL environments. What is also needed is a particular design approach called interaction design.

Social Affordances

Kreijns, Kirschner, and Jochems (2002) defined *social affordances*—analogous to technological affordances—as the "properties of a CSCL environment that act as social-contextual facilitators relevant for the learner's social interaction" (p. 13). Objects that are part of the environment can possess these properties; hence they are designated social affordances devices. When learners perceive social affordances, they are encouraged to engage in activities that are in accordance with these affordances; that is, there can be social interaction.

In the physical world, affordances abound for casual and inadvertent interactions. In the virtual world, social affordances must be designed and must encompass two relationships. First, there must be a reciprocal relationship between group members and aspects of or devices in the environment. The environment must fulfill the social intentions of members as soon as the intentions crop up, whereas the social affordance devices must be meaningful and support or anticipate the social intentions. Second, there must be a perception-action coupling. Once a group member steps onto the social stage and becomes salient (perception), the social affordance devices will not only invite, but will also allow, encourage or even guide another member to initiate a communication episode (action) with the salient member. Salience depends on factors such as expectation, focus of attention, and/or current context of the fellow member. A CSCL environment bereft of social affordances is likely one that isolates learners from their peers.

Educational Affordances

Kirschner (2002) defined *educational* affordances as those characteristics of an artifact that determine if and how a particular learning behavior could possibly be enacted within a given context. In other words, the chosen educational artifact is instrumental in determining if and how individual and team learning (e.g., collaborative learning) can take place. Educational affordances can be defined—analogous to social affordances—as the relationships between the properties of an educational intervention and the characteristics of the learners that enable particular kinds of learning by them.

Educational affordances in distributed learning groups encompass the same two relationships as all other affordances. (a) The environment must fulfill the learning intentions of the member as soon as the intentions crop up, and the affordances must be meaningful and must support or anticipate the learning intentions of the group member. (b) Further, once a learning need becomes salient, the educational affordances of a device or of a learning environment will not only invite but will also guide the member to make use of a learning intervention to satisfy that need. The salience of the learning intervention and hence the degree of affordance of that intervention may depend on factors such as expectations, prior experiences, and/or focus of attention.

DESIGN GUIDELINES

At this point, it is clear *what* has to be designed: technical, educational, and sociable CSCL environments. A next step is *how* such CSCL environments should be designed and implemented. Because affordances, as should be clear now, are not simply designable and developable independent features of a system—artifacts—but rather are dependent on the relationship between the artifact and the organism—the user—how to design them is not simply an interface design question, but rather one of interaction design. Interaction design is closely linked to, but different from, human-computer interaction. As a relatively new field, interaction design has, as yet, no commonly agreed on definition and exact scope. In addition, it lacks a thorough theoretical framework, although researchers are trying to propose one (e.g., Forlizzi & Ford, 2000). However, it is clear that interaction design is concerned with aesthetics (or attractiveness) and emotion, and with the usability of user

interfaces (Alben, 1997; Löwgren, 2002; Norman, 2002).

Interaction Design and The User Experience

To define interaction design more precisely, it is necessary to separate the two terms, *interaction* and *design,* and find out what definition or description applies to each. Shedroff (2001) saw interaction as a continuous process of action and reaction between two parties, living or mechanical. Krippendorff (1989) elicited an etymology of design that goes back to the Latin root *signare,* which means making something, distinguishing it by a sign, giving it significance, designating its relationship to other things, owners, users, or goods. Based on this original meaning Krippendorff stated that design is making sense (of things). The two insights can be combined to construct a definition. Reimann (2001) defined interaction design as "a discipline dedicated to define the behavior of artifacts, environments, and systems (i.e., products)"

How is interaction design different? According to Thackara (2001), interaction design determines "the value of a communication service to its users, and the quality of experience they have when using it."

Why is interaction design important? Interaction design does not concern itself only with the usability, but also with the utility of the system—the set of functionalities a system incorporates. Together, these form the usefulness of a system and are the goals of interaction design. A system that is usable but does not have the functionalities the user needs, is worthless. In CSCL environments the utility is determined by both its educational and social functionalities (see Figure 2).

Interaction design is also concerned with aesthetics and emotion, and how the interaction may appeal to and benefit users inclusively. Norman (2002) suggested that aesthetics and usability are as connected as affect and cognition. He claimed to have evidence that pleasant things work better and are easier to learn, and that attractive things work better. In terms of social affordances, this means that designers should make the social affordance devices not only usable, but also attractive. A real-life example of such a social affordance device is the mobile phone. Although most mobile phones have similar functionalities and comparable usability, some can be personalized by choosing a different "skin" (front cover), making them more attractive for their users. Even when another phone is easier to use, people tend to prefer the more attractive version. Likewise, this should be a goal for social affordance devices in software.

The ultimate goal of interaction design can be

Figure 2 ☐ Usefulness is determined by various types of affordances.
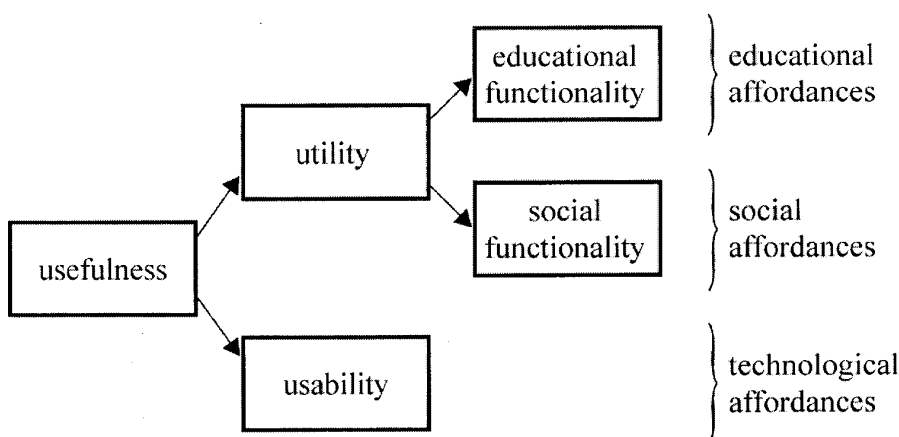
summarized as the user experience. Preece, Rogers, and Sharp (2002) explained that interaction design is "about creating user experiences that enhance and extend the way people work, communicate and interact" (p. 6). If the user experience is the ultimate goal of interaction design, then it is important to define what user experience is, and to determine whether or not it is one dimensional. Kirschner (2002; Kirschner, Martens, & Strijbos, 2004) presented a 6-stage model for interaction design of environments (see Figure 2). This model—as can be seen in the separate steps that it entails—is directed at determining the perceptibility, usability, and utility (i.e., the usefulness) of the reciprocal relationships, and the presence or absence of the required perception-action coupling of the affordances that the designer implements in the design. In this model, the designer must:

1. *Determine what learners actually do.* Watch students interact, observe collaborating groups interacting to solve problems, observe users interacting with software, and so forth, and do this *before* designing and developing.

2. *Determine what can be done to support those learners.* Determine, based on Stage 1, what actually needs to be supported or afforded, and then proceed.

3. *Determine the constraints of the learner, learning situation and learning environment and the conventions that already exist.* Look further than the technological constraints and conventions and take into account the educational and social constraints and conventions that play a role in collaborative environments.

4. *Determine how learners perceive and experience the support provided.* There is a world of difference between (good) intentions and user perceptions thereof. Research and design must be carried out as iterative, interacting processes. New products must be tried out with intended users at stages in their development where physical and conceptual changes can still be made.

5. *Determine how the learner actually uses the support provided.* Analogous to Stage 1, and following up the more formative evaluations carried out in Stage 4 determine if the learner actually does what is hoped or expected.

Figure 3 ☐ 6-Stage model of interaction design.
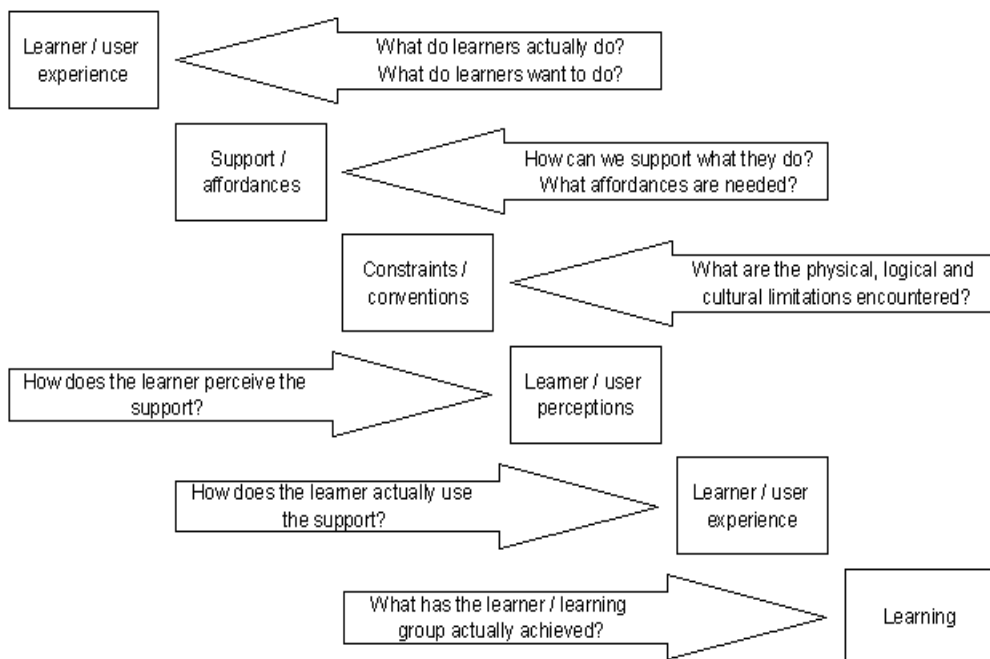
6. *Determine what has been learned*. The goal of education is learning. There are three standards to determine the success of any interaction design: (a) its effectiveness, (b) its efficiency, and (c) its ability to satisfy those using it; in the case of CSCL environments, either those learning or those teaching. An increase in one or more of the standards without a concomitant decrease in any of the others means success. This is the proof of the pudding.

These six stages provide a general approach to interaction design of instructional CSCL environments. However, this design also needs to ensure that the type of social interaction regarded as supportive for competency development actually occurs. Thus, complementary to the 6-stage model, a more specific, process-oriented, design methodology is needed to supply the designer with those questions that must be answered in Stage 3 of the general design level. Process-oriented instructional methods may stimulate designers to adopt a probabilistic approach to CSCL design according to the expected interaction, paying attention to critical

elements (constraints) affecting the interaction (see, e.g., Strijbos, Martens, & Jochems, 2004).

Since most educational design for skills or competence-based education (e.g., problem-based, project-centered, case-based, etc.) tends to focus on the task, we will focus more specifically on operationalizing educational affordances through a critical element that affords the interaction between students: the task. Task ownership, task character, and task control are defining factors in the educational affording of environments (see Figure 4).

Task Ownership

Task ownership in a group is influenced by two pedagogical principles, (a) individual accountability, and (b) positive interdependence. *Individual accountability* (Slavin, 1980) was introduced to counter the "free rider" or "hitchhiking" effect: Some students would not invest any (or only a minimum of) effort into group performance. By stressing individual accountability, what the group does as a whole becomes less important. It is perfectly valid that, in a group environment, each group member is indi-

Figure 4 □ Three dimensions of educational tasks.
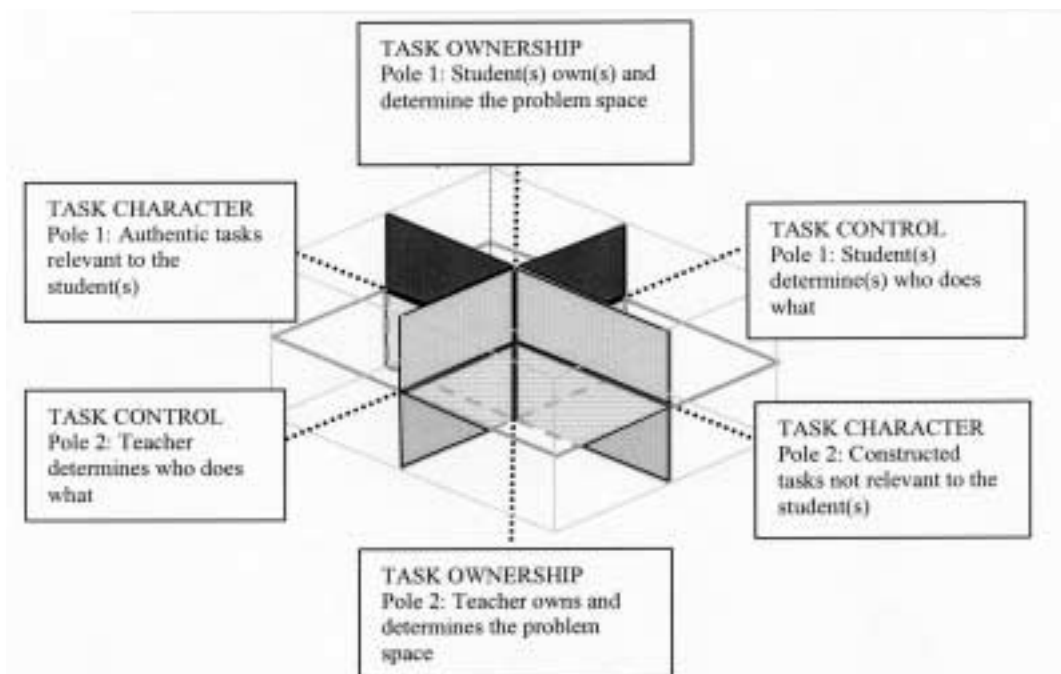
vidually accountable for his or her own work. For example, in many problem-based learning environments, the students' sense of individual ownership is increased through grading them for their individual effort, irrespective of group performance. *Positive interdependence* (Johnson, 1981) reflects the level to which group members are dependent upon each other for effective group performance (enhanced intragroup interaction). Positive interdependence holds that each individual can be held individually accountable for the work of the group, and the group as a whole is responsible for the learning of each individual group member. Essential here are social cohesion and a heightened sense of belonging to a group. Positive interdependence is evident when group members in a project-centered learning environment carry out different tasks within a group project, all of which are needed in the final product. Interdependence can be stimulated through tasks, resources, goals, rewards, roles, or the environment itself (Brush, 1998).

Positive interdependence, in turn, provides the context within which *promotive interaction* takes place. According to Johnson and Johnson (1996), promotive interaction "exists when individuals encourage and facilitate each other's efforts to complete tasks in order to reach the group's goals." (p. 1028). In other words, individual accountability, positive interdependence, and promotive interaction counter the tendency toward hiding and anonymity.

Task Character

Traditional school tasks are artificial in that they are usually very well structured, short in length, well defined, oriented toward the individual, and designed to best fit the content and not reality; in other words, they are designed to fit well into the world of knowledge. An archetypical problem is, "Two trains traveling in opposite directions . . ." At the other end of the continuum are real-life (authentic) problems that are almost always ill structured (Mitroff, Mason, & Bonoma, 1976) and/or wicked (introduced by Rittel & Webber, 1973/1984; see also Conklin & Weil, 1997). They are often so complex and multifaceted that they can be solved only by multi-disciplinary groups working together, where the group members assuage cognitive conflict, elaborate on each other's contributions and coconstruct shared representations and meaning. Examples of wicked problems are building a new type of automobile, legalizing marijuana, and so forth.

Complex ill-structured problems require a different educational approach than simple, well-defined ones. To educate people to be able to solve these types of problems we need to choose a whole-task approach, because real-life tasks are not merely neat segments of some idealized whole, designed for the world of learning. Many researchers (e.g., Hannafin, Land & Oliver, 1999; Jonassen, 1999; Mayer, 1999; Van Merriënboer, 1997) have agreed that transfer-oriented learning can best be achieved through the use of realistic learning tasks consisting of a task description, an authentic environment to carry out the task, and cognitive feedback on the quality of the task performance.

This, however, is often easier said than done. Realistic whole tasks are often too difficult for novice learners without some form of simplification. One form of simplification is through segmentation of the whole learning task into smaller task assignments, thereby dividing the problem-solving process into phases (Nadolski, Kirschner, Van Merriënboer, & Hummel, 2001). That is, dividing whole tasks into nontrivial, authentic part tasks that often aim at achieving epistemic fluency, or as Morrison and Collins (1996) said, "the ability to identify and use different ways of knowing, to understand their different forms of expression and evaluation, and to take the perspective of others who are operating within a different epistemic framework" (p. 109). Typical epistemic tasks are those that stimulate the learner to describe, explain, predict, argue, critique, explicate, and define (Ohlsson, 1996), because they indicate the discourse-bound activities that learners will have to fulfill during collaborative learning and working.

Task Control

Task control is essentially the same as learner control, which has had a somewhat fluid and eclectic history. In its broadest sense, learner

control is the degree to which learners can direct their own learning experiences (Shyu & Brown, 1992). More specifically, learner control is the degree to which individuals control the path, pace, content and/or contingencies of instruction (Hannafin, 1984). New learning paradigms and new technologies expand this concept of control because they make it possible to provide learners with control over depth of study, range of content, number and type of delivery media, and time spent on learning. With these options, learners can tailor the learning experience to meet their specific needs and interests. For this reason, learner control is not "a unitary construct, but rather a collection of strategies that function in different ways depending upon what is being controlled by whom" (Ross & Morrison, 1989, p. 29). Indeed, learner control may be a continuum of instructional strategies in which the learner is provided with the option for controlling one or more of the parameters of the learning environment (Parsons, 1991), such as the learning context, the relevant content, the sequencing and pacing of instruction, the availability and type of feedback and reinforcement, and possibly even the presentation style. An underlying assumption is that learners are amply self-sufficient to be given control over their own learning activities and collaboration methods. This point however, is not undisputed (e.g., Clark, 1988).

Finally, task control is increasingly being seen as not being limited to one dimension. There is growing evidence that student centeredness and teacher centeredness are two separate dimensions, at least in the perception of students and teachers.

THREE RESEARCH PROJECTS AT THE OPEN UNIVERSITY OF THE NETHERLANDS

What follow are examples of three projects being carried out at the moment of this writing, each of which deals with one of the three major thrusts of this article:

1. Affecting the three defining factors in the educational affording of environments by providing functional roles in collaborating teams.

2. Designing and implementing social affordances in CSCL environments via the design and implementation of a group awareness widget.

3. Applying interaction design in the design of collaborative learning tools in the form of research on the effect of a formalism to support common ground in the solution of complex problems.

Providing Functional Roles

The first research project discussed here focuses on the effect of functional roles that provide context-independent process support—developed for higher education—on group interaction and, specifically, coordination during project-based learning. CSCL environments at the Open University of the Netherlands are primarily text-based asynchronous learning systems. Introducing students to the communication and technological tools to support this learning challenges them by figuratively throwing them in the deep end of an unfamiliar realm. An approach to support student groups in such asynchronous communication settings, and the ultimate coordination of their learning, are the uses of functional roles in collaborative groups (Brush, 1998). Roles promote group cohesion and responsibility (Mudrack & Farrell, 1995), thus they can be used to foster positive interdependence and individual accountability, contributing in turn to a feeling of (task) ownership.

Because the sense of belonging to a group is essential to team formation (Forsyth, 1999), functional roles can provide a social affordance for developing group cohesion and a sense of responsibility, as well as stimulating social interaction between group members. At the same time, roles also provide an educational affordance, given the assumption that they decrease coordination communication (i.e., the discussion of who does what) in favor of more task-focused communication. In addition, the functional roles used are context-independent and thus transferable to other content domains in which project-centered work is conducted. The CSCL environment—the technological affordance

offered to the group—is based on only one type of computer-mediated communication, e-mail.

Method

Eighty students enrolled in a course on policy development (49 male and 31 female, age 23–67 years, $M = 34.4$, $SD = 9.03$). The design was a quasi-experimental random independent groups design with the manipulation being the introduction of four functional roles in half of the groups (distributed by the members among themselves), aimed at promoting the coordination and organization of activities essential for the group project. The other half of the groups was completely self-reliant with respect to organization and coordination of their activities. Each group consisted of four students. Throughout the course they communicated electronically by e-mail. Their task was to write collaboratively a policy report containing advice regarding reorganization of local administration, a topical subject in the Netherlands (and a very wicked problem). In terms of the three task constraints that affect group interaction, the task was teacher owned (i.e., set by the teacher), ill structured (i.e., a complex case study with no single correct answer) and controlled by the students (i.e., although an absolute limit was set by the teacher, the students determined their study pace).

To assess the effect of the functional roles on performance, group grades were compared. To assess the effect of the roles on perceived collaboration, each student's self-report perception of their team development, group process satisfaction, task strategy, level of intragroup conflict, quality of collaboration, and usefulness of e-mail were measured. Out of the 80 students enrolled in the course, 43 completed the course successfully (53.8%), of which 33 students in 10 teams returned the evaluation questionnaire (76.7%): role ($n = 5$, $N = 14$) and nonrole ($n = 5$, $N = 19$). Finally, all e-mail communication of the groups that successfully finished the course was analyzed to investigate the actual behavior and the extent to which roles had an effect on coordination and content-focused statements in the messages.

Analysis methodology

Multilevel modeling: In research on cooperative learning, analysis of variance is frequently used to investigate the impact of an instructional strategy using individual level observations (see Slavin, 1995). This type of analysis, however, is not particularly suited to data on student perceptions of group performance, because these perceptions depend on the activities of the other group members. Stevens (1996) pointed out that the assumption of independence is violated, which increases as a function of the interdependence in a group, thus yielding a major increase of a Type I error (Snijders & Bosker, 1999). Multilevel modeling appears better suited to investigate questionnaire data that consist of individual self-report perceptions of group-level variables (cf. Bonito, 2002).

Content analysis: The content analysis data consisted of the e-mail messages contributed by all group members of those groups that finished the course, regardless of whether individual students finished the course or returned the evaluation questionnaire (role and nonrole, $n = 5$ and $N = 20$). All messages were segmented into units of analysis. Strijbos, Martens and Prins (2003) have developed a procedure to segment text-based communication in units defined as a sentence or part of a compound sentence that can be regarded as a meaningful sentence in itself, regardless of coding categories. Punctuation and the word *and* are used as markers for segmentation, but this is only performed if both parts before and after the marker are meaningful sentences themselves. Intercoder reliability of two trials was .82 and .89 (proportion agreement), and a cross-validation check on an English language data set revealed a proportion agreement of .87 (Strijbos, Martens, Prins, & Jochems, in press). To analyze the content of these units, a coding scheme was constructed consisting of five main categories: (a) task coordination, (b) task content, (c) task social, (d) nontask, and (e) not codable. Reliability for the coding was acceptable (Cohen's kappa = .70; cf. Landis & Koch, 1977).

For a thorough discussion of the results and methodological considerations (for both the

multilevel modeling and content analysis) see Strijbos, Martens, Jochems and Broers (2004). For more detail about the content analysis procedure see Strijbos, Martens, Prins and Jochems (in press).

Results

A nondirectional Mann-Whitney test revealed no significant differences between conditions with respect to the group grade ($U = 5.500$, $df = 4$, $p > .05$). Several scales in the self-report questionnaire comprised a single latent variable that was interpreted as perceived group efficiency (PGE).

Multilevel modeling was performed on the obtained PGE scores, but the analyses revealed no difference between the role and nonrole condition regarding PGE using a fixed or random slope model. However, an *F* test for homogeneity of variances to investigate the hypothesis of equality of variances in both conditions for the model without random slope ($F = 2.86$, $df = 4$, $p > .10$) and the model with random slope ($F = 5.86$, $df = 4$, $.05 < p < .10$) revealed a tendency with respect to student awareness of group efficiency. Content analysis corroborates this interpretation.

A nondirectional Mann-Whitney test revealed a significant difference with respect to task-social statements in the messages ($U = 2.500$, $df = 4$, $p < .05$). The students in the role condition contributed more statements expressing either a positive or negative evaluation or attitude in general, toward the group or toward an individual group member. Furthermore, there were more task-content statements in the messages in the role condition ($U = 3.000$, $df = 4$, $p < .05$). However, the assumption that this would be due to a decrease in the amount of coordinative statements was not confirmed. In fact, a directional test revealed that the amount of coordinative statements in the role groups also increased ($U = 4.000$, $df = 4$, $p < .05$; one-sided). Apparently, functional roles stimulated coordination and, as a result, task-content statements increased as well ($r = .73$, $p < .01$).

The previous reported questionnaire return rates indicate a high dropout rate, but this is not uncommon in distance education (Martens, 1998). A specific comparison of course dropout reveals no differences between conditions. However, a comparison of the total number of students that did not finish the course reveals a significant difference with respect to the distribution ($\chi^2 = 6,118$, $df = 1$, $p < .05$). Eighteen students in the nonrole condition—compared to 8 students in the role condition—failed to finish the course in time.

Conclusion

On the one hand, no direct relationship was observed between the instructional intervention and learning outcomes. This is most likely because of a lack of variance, as most grades were between 6 and 8 on a 10-point scale. Moreover, most educators tend not to give unsatisfactory marks to a group, as this would be detrimental to individual group members who invested effort in the group project. On the other hand, content analysis revealed that the assignment of functional roles increased both coordinative and content focused statements, which are important prerequisites for any interaction or collaborative learning to occur. In sum, this study on the function of roles illustrates that sole focus on group-performance outcomes in terms of grades (or test results) as indications of successful collaboration is not enough. The study of the environment requires triangulation of research methods and different types of data to construct a representation of the collaborative process.

Designing a Group Awareness Widget

The aim of the second project was to create sociable environments that meet as much of the social needs of learners as possible through the explicit embedding of social functionality based on social affordances. Researchers within the area of computer-supported collaborative work have already become aware that such sociable environments are needed by virtual groups (Donath, 1997; Feenberg, 1989). Bly, Harrison, and Irwin (1993) argued that the "smooth integration of casual and task-specific interactions, combined with the ability to meet informally as well as formally, is a critical aspect of productive group work" (p. 29). In contrast, they observed that:

Figure 5 ☐ The prototype Group Awareness Widget.
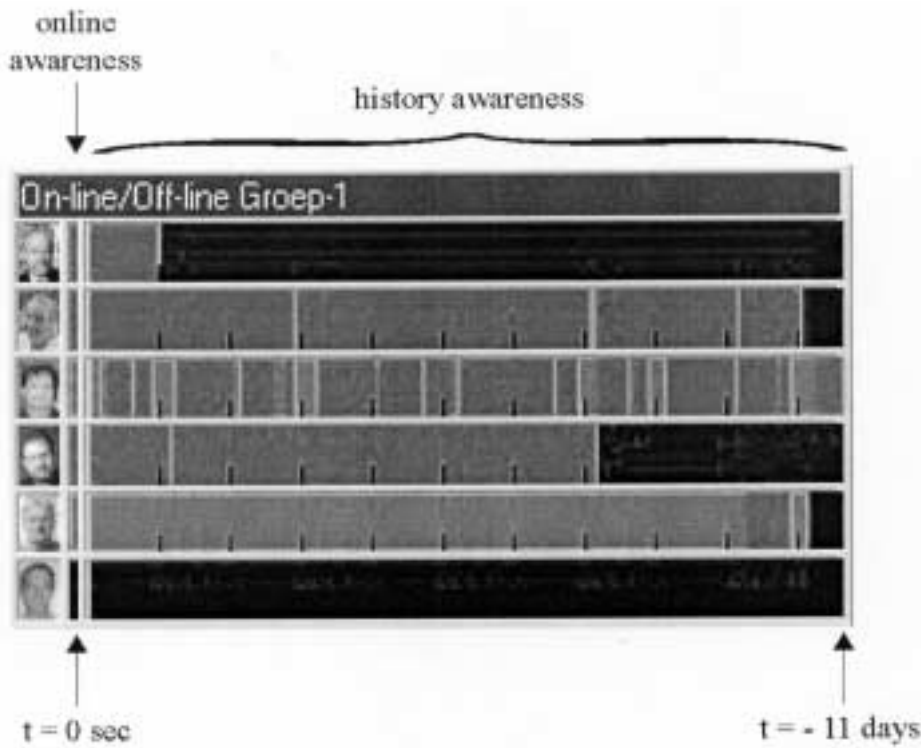
Most tools in computer-supported collaborative work (CSCW) are devoted to the computational support of task-specific activities, but support for cooperative work is not complete without considering all aspects of the work group process. When groups are geographically distributed, it is particularly important not to neglect the need for informal interactions, spontaneous conversations, and even general awareness of people and events at other sites. (p. 29)

The kind of social affordances we wish to implement focus on stimulation of informal and casual conversations, stimulation of impromptu encounters, and bridging the time gap imposed by asynchronicity. All three aims imply proximity to be an important dimension of social affordances. The first two aims address proximity of place (i.e., spatial proximity) and the latter addresses proximity of time (i.e., temporal proximity) that can be bridged by using traces or footprints which introduce a form of history awareness (Kreijns, Kirschner, & Jochems, 2003). Up until now, this solution of using footprints has seemed to be appropriate, and generally

accepted by the community of computer-supported collaborative work and HCI: for example, the concept of social navigation (Munro, Höök, & Benyon, 1999) is based on the use of footprints (Wexelblat & Maes, 1999).

In CSCL environments, social affordance devices may be operationalized by *group awareness widgets*—software tools providing:

1. *Group awareness for achieving teleproximity.* The group awareness information is presented graphically to the user (i.e., the learner).

2. *History awareness* (i.e. the structured collection of all footprints) for achieving an overview of temporal proximities. History awareness information is also presented in a graphical manner to the user.

3. *Communications media* for achieving *perception-action coupling.*

Based on the social affordances framework, we implemented a first prototype of a group awareness widget (see Figure 5). As a first step,

not all implications of the framework are implemented; the communications media contain the traditional media (chat and e-mail). Pictures of the participants are used.

The window has a time axis along which strokes are displayed. The stroke length is an indication of the duration of the engagement. Each member is displayed with her or his strokes. Green (dark grey if printed) means online, red (lighter grey if printed) means off-line. Black means that there is no history data available for displaying. As can be seen from Figure 5, history awareness is limited to 11 days; days are separated from each other by small vertical black strokes. Clicking on the portrait of a group member or on a stroke opens a dialogue box from which the communication channels are accessible. The dialogue box also contains personal and business information about that group member.

We hypothesize that as simple as this single segment of the group awareness widget is, it may already invite the group learner to initiate a communication episode that is not based on the learning tasks to be done. It provides the group member with information that may stimulate social interaction with others in the following ways:

- Perception that the group member is not alone in the environment, even when there are no group members currently online; group members may show up at regular times providing opportunities for future contacts in real-time.

- Emergence of patterns of busy times.

- Possibility of initiating a real-time conversation with currently online group members (i.e., a chance encounter) or sending a message to a group member who is currently off-line.

In addition to the framework of social affordances, this project also encompasses the concepts of *sociability* and *social presence*. The sociability of CSCL environments refers to how they can differ in their ability to facilitate the emergence of a social space: the human network of social relationships between group members that is embedded in group structures of norms and values, rules and roles, beliefs, and ideals.

Social presence (Short, Williams, & Christie, 1976) refers to the "degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships" (p. 65). It is thus the degree of illusion or perception that the other in the communication appears to be a real physical person. Social presence affects the degree of social interaction taking place in CSCL environments (Gunawardena, 1995; Tammelin, 1998; Tu, 2000, 2002; Tu & Isaacs, 2002).

To this end, instruments have been developed that measure the degree of sociability, social space, and social presence (Kreijns, Kirschner, Jochems, & Van Buren, 2004). Testing if and how group awareness affects the degree of sociability, social space, and social presence, and eventually leads to better learning in teams is the focus of this research. More precisely, we want to test the following hypotheses:

Hypothesis 1: Social affordance devices contribute to the degree of perceived sociability of CSCL environments.

Hypothesis 2: CSCL environments higher in perceived sociability will increase the likelihood of the establishment of a sound social space.

Hypothesis 3: CSCL environments higher in perceived sociability will increase the degree of perceived social presence.

Hypothesis 4: A higher perceived social presence will increase the likelihood of the establishment of a sound social space.

Currently, a series of experiments are being conducted to test the hypotheses. If these hypotheses prove to be true then we may design alternative group awareness widgets that have a completely different look and feeling. We may test the alternatives to examine if they are more powerful than the originals, in the sense that they are better social affordances devices. Using this strategy may ultimately lead to most satisfying sociable CSCL environments.

Studying a Formalism to Support Common Ground

When teams have to solve particularly complex, or wicked, problems they often face a lack of common ground. The third study discussed here aimed at facilitating grounding in such situations (see Beers, Boshuizen, & Kirschner, 2003, for a more detailed description of this study). The main objective of the research was the interaction design of social-technological affordance devices that invite users to negotiate meaning while collaborating in solving complex problems. This specific project was carried out to determine if a *negotiation widget*—part of a graphical user interface that displays information and invites users to act in a number of ways—would positively affect the process of negotiating common ground.

The process of negotiation starts when a team member makes as yet unshared knowledge explicit or tangible to others. This can be oral, written, or symbolic. After one team member has made a contribution, others can try to understand it. In doing this they can consider aspects of the contributor (e.g., educational background, domain of expertise, political views, etc.) as well as their own beliefs and assumptions. A contribution is thus understood against the presumed perspective of the other, as well as against one's own perspective (Bromme, 2000). According to Clark and Schaefer (1989), the process of grounding continues until "the contributor and the partners mutually believe that the partners have understood what the contributor meant to a criterion sufficient for the current purpose" (p. 262). This framework served as the basis for the design of a tool for helping asynchronously collaborating students in teams to achieve common ground.

CSCL environments often make use of external representations formed or restricted by a *formalism*—a set of objects and rules for making an external representation. In this research a formalism for facilitating negotiation of common ground in problem-solving groups was developed and tested. We expected the formalism to result in more negotiation activities and, ultimately, more common ground. In the research presented we made use of a pen-and-paper approximation of the formalism in an interaction design framework. All six stages of the interaction design model (see Figure 3) were implemented such that—based on the results of the research reported in this section—the formalism was embedded in a newsgroup environment that is presently being evaluated. The newsgroup was modified to allow the implementation of a widget that defines specific message types (i.e., contribution, clarification, verification, and elaboration), and specific rules about when one was allowed to post messages of certain types.

Method

We studied students collaborating in a face-to-face setting who were required to make use of a pen-and-paper approximation of the negotiation formalism to solve a complex economics problem derived from a dynamic economics game. First, the participants were allowed to practice with the simulation individually, and to posit a solution to the case individually, so that they were able to fully apply their own perspective to the task. Next, they solved the problem collaboratively, and after that were again asked to formulate an individual solution. All resulting individual problem representations and solutions, as well as the resulting group problem representation and solution, were recorded. The collaboration process was also videotaped for analysis (with Noldus Observer® software).

Procedure

Groups using the formalism were compared with groups not using the formalism, in other words, groups that worked idiosyncratically. A coding scheme for analysis of negotiation of common ground was developed consisting of the following categories:

- Contribution—new conversation topics,

- Verification—verifying one's own understanding of another's utterance,

- Clarification—clarifying the intended meaning of a previous utterance as a reaction to a verification, and

- Elaboration—continued discussion of a topic,

without verifying and clarifying the intended meaning of the utterances.

A high number of clarifications and verifications was seen as indicating explicit negotiation processes. The reliability of the coding and coding procedure was determined by comparing a sample of 25 min of video-data (9% of total data) as coded by two coders. This resulted in a substantial (see Landis & Koch, 1977) inter-rater reliability as determined by a Cohen's kappa of .68 (SE = .066). All further data were coded by one of the coders.

As an indication of common ground, overlap between the individual problem representations of the different participants after problem solving was determined. To do this, discussion topics were identified to characterize the content of individual representations and were subsequently investigated to determine whether they were present in individual representations after collaboration. The extent of overlap between the discussion topics during and after collaboration was used as an indication for common ground.

Results

Results indicated that the formalism-groups spent more time on negotiation than did the nonformalism-groups (i.e., groups that used their own idiosyncratic representation method) as reflected by the number of utterances that were representative of negotiation (see Table 1). The formalism groups also discussed more *different* topics than the idiosyncratic groups, and

more members of the formalism groups participated in discussion (participants per segment) than in the idiosyncratic groups. These results suggest a more equal representation of the different perspectives in the collaboration process of the formalism groups than in the idiosyncratic groups. We conclude that the formalism affects negotiation processes by making the contributions more explicit.

The results on common ground are somewhat less clear (see Table 2). Although the formalism groups discussed *more* different discussion and their members explicated more different discussion topics in their individual problem representations, the idiosyncratic groups captured more discussion topics in their group external representation than the formalism groups (M = 13.0 vs. M = 10.7). Also, the number of discussion topics was the same for both conditions (M = 2.0, number of discussion topics in three individual representations), indicating that there was no difference in common ground. A note of caution is needed here. It may have been the case that our choice of describing information content on the contribution level was too crude to see differences in common ground between groups. It remains uncertain whether the formalism influenced the extent to which common ground was negotiated.

Based on these tentative results, both the formalism and the coding scheme have been refined. The formalism was translated into two variations of a negotiation widget for synchronous or asynchronous distributed learning

Table 1 □ Differences in use of categories.

	Mean		Standard deviation	
	Formalism	*No formalism*	*Formalism*	*No formalism*
Time	3182.00	2341.00	390.58	579.66
Contribution	25.00	19.30	4.36	4.51
Verification	38.00	19.30	5.20	8.50
Clarification	46.00	26.70	7.21	6.66
Elaboration	118.00	102.00	34.51	17.44
Negotiation[a] per contribution	3.37	2.38	.09	.58
Participants per segment	2.67	2.47	.09	.07

[a] Negotiation = negotiation of meaning = sum of verifications and clarifications.

Table 2 ☐ Common ground.

	Mean		Standard deviation	
	Formalism	*No formalism*	*Formalism*	*No formalism*
Total number discussion topics	25.0	19.3	4.36	4.51
In the group external representation	19.3	12.0	9.50	5.56
In the group solution	8.7	2.3	2.52	1.15
In one individual representation	6.3	6.3	3.06	2.08
In two individual representations	4.0	2.0	3.00	1.00
In three individual representations	3.3	2.3	3.08	2.31

groups. One variant is a noncoercive tool to support users in negotiation. That is, it does not force them to negotiate in a certain way (e.g., every verification must be followed by a clarification or a new concept may not be introduced until the previous one has been fully verified and clarified by all participants). The second variant is coercive. Future research will be focused on both the further interaction design of a usable negotiation tool and the effect of coercion on tool use, and value in the negotiation process in solving complex problems.

In sum, these three projects illustrate the importance and impact of affordances—technological, educational and social—for designing CSCL environments, as well as the need for interaction design that specifically addresses the issues of user experience, which are affected—among other critical elements or constraints—by the level of task ownership, task character, and task control.

CONCLUSIONS

This article presents a framework for designing and developing electronic collaborative learning environments based on two separate principles, (a) the systemic and emergent properties of educational, social, and technological affordances and (b) the implementation of interaction design to assure both usability and utility.

The concept of three types of affordances (i.e., technological, educational, and social) is central to design, specifically in those cases where the learning environment centers on collaboration. Their design and use is an example of studying

phenomena in terms of their systemic and emergent properties (in contrast to reductionist thinking, which tries to explain system behavior in terms of the behavior of subsystems). In such a way of thinking, CSCL environments are seen as systems that have interacting parts (i.e., artifacts related to technological, educational, and social affordances) and emergent properties that exceed the sum of the properties of their parts. With respect to the design of computer-supported learning environments, it is not of primary importance what exactly is caused by different elements of the learning environment (learning is no longer causal or deterministic, but has become probabilistic). This has consequences for the approach toward the designing of (computer-supported) collaborative learning environments. More important is whether the elements of a learning environment *afford* the type of competency development that was targeted. With respect to collaboration, the question is whether the elements of the environment afford the *emergence* of that type of (social) interaction that is supportive for the acquisition of the targeted competencies.

But these questions cannot be easily answered. We as designers often think that we know what our designs and products will do and how learners will use them. Unfortunately, this is almost never the case. Each of the phases in the design process needs to be studied with respect to the specific choices that can and must be made (see Figure 2). Some research is basic, such as studies of interface design, or that the way information is presented affects cognitive load and learning (e.g., Kester, Kirschner, & Van Merriënboer, 2004). Other studies are more

developmental in nature, such as research on how group awareness widgets affect the perception of sociability, social space, and social presence (Kreijns & Kirschner, 2002). And still other research is even more applied, such as how specific learners or learner groups perceive a specific computer-supported learning environment.

Design of CSCL environments needs to be carried out according to the six stages of the interaction design model presented here (see Figure 3). Though teachers and designers would probably prefer a set of deterministic design rules (i.e., do *A*, then *B* to achieve *C*), a checklist with a limited number of categories is not the answer. We have in this article, however, provided an interaction design model to stimulate educators, educational designers and technologists, and educational researchers to think more deeply about their instructional decisions, and not simply to rely on traditional approaches. □

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