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Designing for interaction: Six steps to designing computer-supported group-based learning

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Abstract

At present, the design of computer-supported group-based learning (CSGBL) is often based on subjective decisions regarding tasks, pedagogy and technology, or concepts such as 'cooperative learning' and 'collaborative learning'. Critical review reveals these concepts as insufficiently substantial to serve as a basis for CSGBL design. Furthermore, the relationship between outcome and group interaction is rarely specified a priori. Thus, there is a need for a more systematic approach to designing CSGBL that focuses on the elicitation of expected interaction processes. A framework for such a process-oriented methodology is proposed. Critical elements that affect interaction are identified: learning objectives, task-type, level of pre-structuring, group size and computer support. The proposed process-oriented method aims to stimulate designers to adopt a more systematic approach to CSGBL design according to the interaction expected, while paying attention to critical elements that affect interaction. This approach may bridge the gap between observed quality of interaction and learning outcomes and foster CSGBL design that focuses on the heart of the matter: interaction.

Keywords: Cooperative/collaborative learning; Computer-mediated communication; Distributed learning environments; Interactive learning environments; Distance education and telelearning

1. Introduction

Learning in small groups has been intensively researched since the 1970s. Moreover, the rapid development of computer support for communication and collaboration stimulated its use for pedagogical practices. At the same time a new way of thinking about instruction emerged, to a

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large extent based on constructivism. According to Reiser (2001), the instructional principles associated with this emergence include requiring learners to (a) solve problems, (b) work together, (c) examine problems from multiple perspectives, (d) become responsible for their own learning process; and (e) become aware of their role in the instructional process. During the past decades (computer-supported) group-based learning CSGBL) has become an important aspect of contemporary education, and is also stimulated through learning environments that increasingly resemble authentic working processes (Bastiaens & Martens, 2000). At present, however, there are no clear guidelines to determine how a CSGBL setting (i.e. learning environment) should be designed (Van Berlo, 2000). Developers question what tasks or work methods should be used (Enkenberg, 2001). Many researchers have indicated considerable variations regarding the quality of interaction and learning outcomes (Häkkinen, Järvelä, & Byman, 2001). To a large extent this is caused by differences in group size, technology used, length of the study, research methodology and unit of analysis (Lipponen, 2001).

At present, the design of CSGBL settings often seems based on subjective decisions regarding tasks, pedagogy and technology. So far, research has mainly focused on the quality of collaborative products or individual learning results, but the outcome is mediated by the quality of group processes (Shaw, 1981). Moreover, there is considerable uncertainty about the relationship between interaction and outcome, because the effect of a CSGBL setting on group interaction is rarely specified a priori (Dillenbourg, 1999). However, recent interest in CSGBL from the instructional design domain may stimulate the development of a more systematic approach to CSGBL design (Gros, 2001).

In this article a framework for a process-oriented methodology to design CSGBL settings is proposed, which focuses on the elicitation of the specified expected interaction. This implies that researchers have a clear concept of interaction and how it relates to their CSGBL setting. Hence, before the process-oriented methodology can be discussed, four issues must be addressed: (a) the applicability of a classic instructional design view to CSGBL, (b) the conceptualisation of interaction, (c) the applicability of the terms 'cooperative learning' and 'collaborative learning' as design principles, and (d) the possibility to identify critical elements in CSGBL settings affecting interaction, and if so, what they are. These issues will be successively elaborated in Sections 2–5. Next, the design methodology is introduced. Finally, the potential applicability and its limitations will be discussed.

2. Instructional design for CSGBL

Classic instructional design focuses on individual learning outcomes and tries to control instructional variables to create a learning environment that supports the acquisition of a specific skill (person A will acquire skill B through learning method C). With respect to CSGBL, the use of groups complicates this view. The key questions are whether it is (a) possible and (b) feasible to pre-define independent static conditions of learning or instruction for a group setting. Can all relevant conditions that affect group interaction and individual skill acquisition be controlled? Regarding the multitude of individual *and* group level variables that may affect CSGBL processes, as well as the difficulties involved in pre-defining independent static conditions, a less stringent view is more useful. Although Gros (2001) indicates a need for a new paradigm of instructional design that expands to CSGBL settings, a first conceptualisation of such a paradigm is lacking. While Nelson (1999) provides design guidelines for teachers and students to guide activities during 'collaborative problem solving' (CPS), such as the teacher role and collaboration procedures, similarly it is specified neither whether these guidelines apply to other CSGBL settings nor how these guidelines affect interaction.

Instead of a classic causal view, the design of CSGBL settings requires a probabilistic view of design (Fig. 1) which corresponds with the distinction by Van Merriënboer and Kirschner (2001) 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, however, designers focus on methods that support the *learning processes*, and not so much on the attainment of pre-defined goals.

A probabilistic view implies that more attention is paid to learning and interaction *processes*, instead of only to *outcomes*, especially with respect to CSGBL: person A in group X may acquire skill B through method C, but equally may acquire only a part of skill B 1/2B or B and something unforeseen (B + U). Sometimes it is argued that the design of CSGBL settings should include individual differences that affect interaction, such as sex, intellectual capacities and social skills (Cohen, 1994). Such a view is mostly generated by an outcome-based perspective towards CSGBL stressing the importance of determining individual learning gains. A process-oriented view, however, treats these differences as '*possibly*' intervening, but not as '*certainly*' intervening with other students' learning. In addition, these individual differences must not be confused with constructed differences that are imposed by the pedagogy, as is the case during Jigsaw (see Aronson & Thibodeau, 1992). Moreover, the effect of individual differences is likely to vary across CSGBL settings. Therefore, since it is difficult to specify a priori which individual differences will affect interaction in a given CSGBL setting, these cannot be included in a process-oriented design methodology, although retrospective analysis may reveal opportunities for re-design to compensate for the effects of individual differences on interaction.

In sum, the proposed CSGBL design methodology that will be discussed in Section 6 should not be seen as a method that ensures learning benefits for all participants (causal). Rather it supports designing a CSGBL setting in which student participation is likely to lead to skill acquisition (probabilistic). If acquisition of learning outcomes cannot be guaranteed, a logical

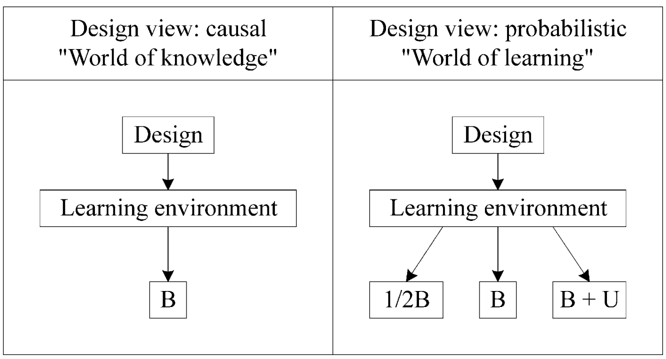


Fig. 1. Two views on instructional design.

step is to focus on the process and identify critical elements (for example task type) that, although variable, shape the core of CSGBL settings, that is interaction. Thus, CSGBL design should enable interaction, seen as most supportive to reach the learning goals, to develop. Designing for interaction in advance, however, requires a clear conceptualisation of the expected interaction.

3. Conceptualising interaction

Collaboration essentially entails interaction. The issue of 'how students interact' has gradually received increasing attention in CSGBL research, but the impact of interaction processes on learning is explained in retrospect, i.e. it is determined whether outcomes were affected by the interaction observed. Retrospective examination of interaction can provide indicative evidence regarding a relationship between outcome and interaction, but there is little certainty that it can be reproduced since it was not planned. Since little or nothing is said about the expected interaction prior to CSGBL, the observed outcomes may equally likely be ascribed to other factors. In order to specify, a priori, how a CSGBL setting affects interaction ''we should stop using the word 'collaboration' in general and start referring to precise categories of interaction'' (Dillenbourg, Baker, Blaye, & O'Malley, 1996, p. 21).

Distinguishing levels of interaction can help to clarify ambiguous terms often used to conceptualise interaction. Rogoff (1995) characterises interaction in terms of three planes of activity: 'guided participation', 'apprenticeship' and 'participatory appropriation'. However, guided participation and apprenticeship both implicitly contain information about the relative status of the actors. Thus it can be questioned whether they affect interaction processes differently. Moreover, King (1999) identifies interaction in terms of 'peer tutoring', 'problem solving' and 'complex knowledge construction', but it is not clear whether 'guided participation' and 'peer tutoring' actually evoke different interaction processes.

The next section discusses three prototypical conceptualisations of interaction, which can be seen as three levels of interaction specification. Level one specifies interaction to the extent of relationships between group members. Level two includes a temporal factor and thus it also specifies the development of those relationships. Finally, level three also includes actual communicative statements or acts during interaction, thus providing further insight into the causes of change and the development of interaction.

3.1. Level one: interaction conceptualised as communication networks

Since the 1950s, communication networks have been an important topic in small group research that has focused on concepts such as 'leadership', 'status', 'organisational development', 'member reactions' and 'problem solving efficiency'. In 1964 Shaw described communication networks for three-, four- or five-person groups that differ in their level of 'centrality' (cf. Shaw, 1981, p. 152). Centrality provides information about which students are central participants (high influence on interaction) and which students are relatively isolated (little or no influence on interaction) (Haythornthwaite, 2001). Although most tasks used in social psychological research hardly resemble constructed 'learning tasks' (let alone authentic tasks), results indicate that decentralised networks outperform centralised networks when the task is more complex (Shaw, 1981).

Recently, CSGBL research has devoted more attention to communication networks between students through Social Network Analysis (SNA) (Wortham, 1999), as an extension to the common methodology of counting statements or length of contributions (Benbunan-Fich & Hiltz, 1999). SNA transforms all contributions into a graphical scheme from which the level of group cohesion can be inferred, using 'centrality' and 'density'. Density provides information about the extent to which students respond to each other (Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2001). However, neither the general 'communication networks' nor the more specific SNA analysis methodology, provide information about the development and change of interaction during CSGBL.

3.2. Level two: interaction conceptualised as temporal communication structures

A first approach to capture development and change in interaction patterns is to conceptualise interaction in terms of successive periods that define group interaction. Social psychology, in general, identifies five stages of group development: orientation, conflict, cohesion, performance and dissolution (Tuckman, 1965; Tuckman & Jensen, 1977). Although Forsyth (1990) indicates that these describe a common developmental pattern, this should be seen by no means as universal. Sometimes groups do not pass through all of these stages. However, they may stimulate educational researchers to specify interaction according to the succession of alternate stages. An example is provided by Jonassen and Kwon (2001) who distinguish stages during group problem solving and conceptualise interaction in terms of the *succession* of these stages.

A more common approach, among educational researchers, to specify a temporal relationship is that of Rafaeli and Sudweeks (1997). They distinguish three modes of dyadic communication: one-way, two-way and interactive communication, and illustrate the difference through a temporal sequence. One-way interaction refers to a situation in which the interaction is dominated by one student, for example a peer tutoring setting. Interactive and two-way cannot be distinguished as straightforwardly as Rafaeli and Sudweeks assume, because 'interactive' is by definition always 'two-way'. Their difference is better expressed by two other labels: 'reactive' ('two-way') and 'reciprocal' ('interactive'), and can be illustrated through an episodic representation (Fig. 2). Episodes are defined by meaningful statements and represent a temporal communication sequence: arrows represent a message within an episode, dotted arrows represent messages that build forth on a message in a preceding episode and constitute the input for messages in the next episode.

Reactive interaction refers to communication in separate episodes, but none of the students interacting build on information previously stated by another student. For example, one student states 'Volcanoes are like mountains', another states 'Lava is hot, so there can be no volcanoes in the sea', and the first states 'Volcanoes sometimes explode', etc. Reciprocal refers to communication that is spread across episodes, but now messages build on the input of preceding messages (italicised in example). For example, one student states 'Volcanoes are like mountains, *but they also produce lava*', another states '*Lava is hot*, so there can be *no volcanoes in the sea*', and the first states '*I read that islands are created by volcanoes*, so there are volcanoes in the sea'.

3.3. Level three: interaction conceptualised as communicative statements or acts

Apart from the temporal element in structural relationships, interaction can also be specified in terms of communicative statements or acts. Interaction specified on levels 1 and 2 does not

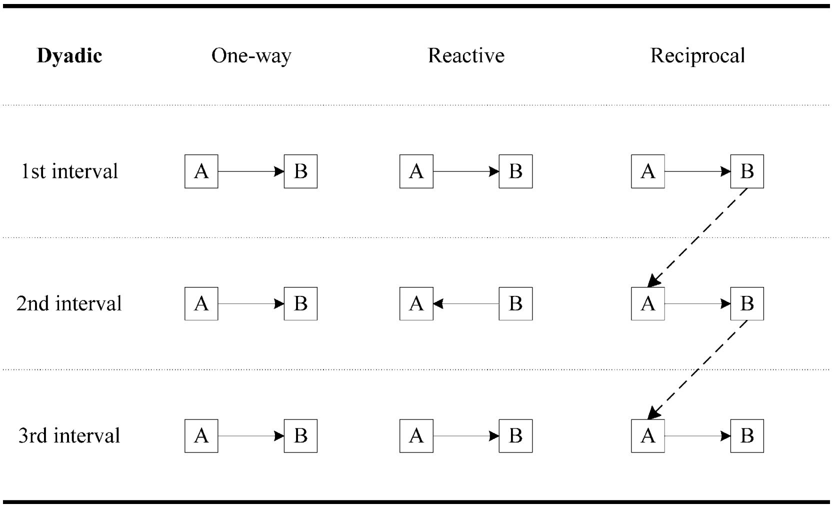


Fig. 2. Typology of level two interaction (dyadic).

provide information on why a person contributes less or why the input of a group member is ignored. To this end many researchers have adopted (sometimes modified) a content analysis approach to computer-mediated communication (CMC) and CSGBL developed by Henri (1992), which distinguishes three main categories of statements: interactive, cognitive and metacognitive (Aviv, 2000; Hara, Bonk, & Angeli, 2000; Gunawardena, Lowe, & Anderson, 1997; Lally & DeLaat, 2002; Newman, Webb, & Cochrane, 1995; Veldhuis-Diermanse, 2002). Another influence on interaction specification at this level is speech act theory that, in essence, aims to relate the way a statement is expressed to its function in the communicative process (Howell-Richardson & Mellar, 1996). Related to this approach is the so-called 'task acts' approach that links communicative acts to specific behaviours that are either supportive of, or in conflict with, effective task performance (Erkens, Jaspers, Tabachnek-Schijf, & Prangsma, 2001).

Content analysis, as well as speech/task act approaches (in general referred to as 'discourse analysis'), can for instance show that a group member contributed less because time had to be devoted to other courses as well. Fig. 3 is an extension of Fig. 2. A prototypical representation of successive communicative statements/discourse acts is added.

In sum, specifying interaction on (at least one of) three different levels can clarify the processes under study, thus enabling researchers to assess the foreseen effect of the pedagogy or technology introduced. These levels of interaction also constitute the basis needed to formulate a process-oriented methodology for CSGBL design, since they are not restricted to specific domains or contexts but apply to any CSGBL situation. Taking interaction as the central object of any CSGBL design requires that critical elements, affecting interaction, need to be identified to construct a process-oriented methodology. Currently, most CSGBL designs are motivated with reference to 'cooperative' or 'collaborative', or principles like 'positive interdependence' and 'individual accountability'. Section 4 addresses their applicability for design of CSGBL settings.

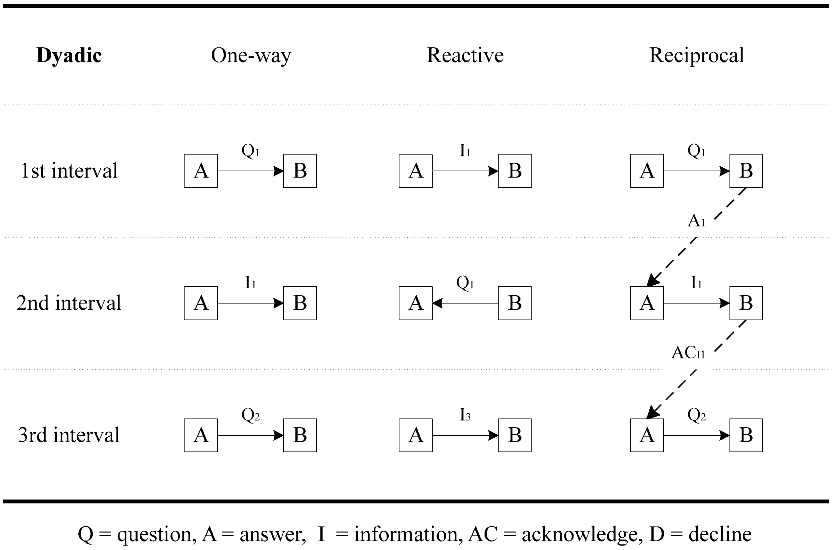


Fig. 3. Typology of level three interaction (dyadic).

4. Cooperation versus collaboration: design principle for GBL?

During the 1970s and 1980s 'cooperative learning' dominated CSGBL practices, but since the beginning of the 1990s 'collaborative learning' came into fashion. Although many researchers make a distinction between these perspectives on CSGBL, there is no agreement on what the distinction actually entails. Panitz (n.d.) sees collaboration as a personal philosophy of group interaction and cooperation as a (set of) structure(s) of interaction that facilitates group performance. Slavin (1997) states that 'cooperative' is being associated with well-structured domains whereas 'collaborative' is associated with ill-structured domains. Millis and Cottell (1998) state that both lie on a continuum: cooperative being the most structured and collaborative the least structured approach. In addition, many researchers emphasise the contributions of group members and associate cooperative with division of labour procedures and collaborative with equality of contributions to a problem solution (Brandon & Hollingshead, 1999; Dillenbourg, 1999; Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, n.d.; Paechter, 2001; Scanlon, 2000). Finally, irrespective of their validity, most distinctions share a uni-dimensional approach for distinguishing both perspectives. Moreover, it is often stressed that there are more similarities than differences between them (Kirschner, 1999). In sum, this leads to the conclusion that cooperative and collaborative are insubstantial as design principles. Although it often seems that both perspectives are based on a design approach, structured versus unstructured, this distinction seems (a) only part of the puzzle and (b) the implications and effects on interaction are hardly made explicit in advance.

4.1. What about positive interdependence and individual accountability?

Most designs of CSGBL settings refer to two central concepts governing group interaction, irrespective of a 'general' cooperative or collaborative approach. Group interaction is generally affected by two well-known principles called 'positive interdependence' and 'individual accountability' (Johnson, Johnson, & Johnson-Holubec, 1992; Kagan, 1994; Lamberigts, 1988; Sharan & Sharan, 1992; Slavin, 1997). Positive interdependence (PI) and Individual Accountability (IA) were introduced in the early 1980s and both relate to well-known phenomena in group dynamics, such as group cohesion and social loafing.

PI refers to the degree to which the performance of a single member is dependent on the performance of all others (Johnson, 1981), as opposed to 'negative interdependence' that stresses competition. PI aims to promote cohesion and a heightened sense of 'belonging' to a group. It can be achieved through the task, resources, goals, rewards, roles or the environment (Brush, 1998). Although PI can have a strong influence on the level of group cohesion, these terms are not interchangeable, because cohesion encompasses many other additional social factors such as mutual trust and familiarity.

IA stands for the extent to which group members are held individually accountable for jobs, tasks or duties, central to group performance or group efficiency (Slavin, 1980). It was introduced to counter the 'free-rider effect': some students would deliberately not invest any (or little) effort into group performance. Thus, IA implies specifying individual responsibility: something someone can be held accountable for. It is related to group dynamics phenomena called 'social loafing' and 'diffusion of responsibility'. Social loafing is a process that refers to members deliberately avoiding effort (so-called 'free riders') and if responsibilities are unspecified or unclear, students may assume, unconsciously, that another member will take up responsibility.

Since PI and IA are both closely related to well-known phenomena in group dynamics research, it can be concluded that, in essence, both are relevant aspects regarding performance and interaction in *any* CSGBL setting. Regardless of how the group cooperates or collaborates, this does not decrease the need to promote cohesion and to avoid 'free-riding'. PI and IA both affect the way in which group interaction is structured (and subsequently interaction). Thus the use or non-use of PI and IA appears equally insufficient to guide CSGBL design. Both are relevant in any setting and their use varies. Moreover, merely focusing on the level of structure provided would not go beyond a previously criticised uni-dimensional approach to distinguish CSGBL settings. Section 5 discusses a multi-dimensional approach that is constituted by five critical elements that affect group interaction.

5. Five critical elements for process-oriented CSGBL design

Although instructional design researchers argue to develop an explicit and systematic approach to CSGBL design (Gros, 2001), it is not a new issue. Salomon argued in 1992 that "the whole learning environment, not just the computer program or tool, be designed as a well orchestrated whole (...) this includes curriculum, teachers' behaviours, collaborative tasks, mode of peer collaboration and interaction, tasks, learning goals and the like" (p. 64).

We propose here a process-oriented approach that focuses on critical elements that affect the emergence of preferred interactions. This multifaceted approach to CSGBL design consists of five elements: three elements are depicted as dimensions: 'learning objectives', 'task type' and 'level of pre-structuring', and vary on a continuum with two poles (cf. Millis & Cottell, 1998), and two in terms of discrete categories namely, 'group size' and 'computer support'.

5.1. Learning objectives

It is important to realise that the use of groups to increase individual learning benefits differs considerably from joint problem solving or collaborative inquiry. If the objective of a CSGBL setting is to assist student A's skill acquisition through student B, this will likely result in a different interaction pattern than when two students collaborate on an inquiry project. According to Slavin (1995), cooperative methods are "most appropriate for teaching well-defined objectives" (p. 5). Cohen (1994) refers to these as 'lower-level skills', but the concept of '*closed skills*' is less debatable. Closed skills are relatively fixed skills that can be learned separately, for instance a procedure for 'long divisions' or 'basic concepts' such as the concept of a variable. Contrasted with closed skills are '*open skills*', such as argumentation and negotiation. A closed skill will not likely elicit intensive interaction, i.e. interaction is prone to evolve around skill execution, and will most probably consist of 'reactive' remarks. Argumentation and negotiation are much more complex skills and, by definition, students not only react, but reciprocally *build on* each other's contributions; thus different types of interaction may be beneficial for learning different skills. In the case of a closed skill, interaction with a more skilled peer may influence an individual's learning, but interaction is essential for argumentation or negotiation skills (i.e. open skills). Thus, a first critical element that needs to be considered prior to CSGBL, because it affects expected interaction, are the learning objectives, which can be depicted on a continuum ranging from '*open skills*' to '*closed skills*'.

5.2. Task type

The second dimension comprises task type. In general, groups tend to be more effective when the task requires a variety of information, consisting of several successive steps, and can be solved by adding individual contributions (Shaw, 1981). Apart from 'additive', group tasks can also be 'disjunctive' (e.g. group performance depends on each individual's math quiz score) or 'conjunctive' (e.g. group decisions through consensus). McGrath and Hollingshead (1994) suggest a different typology and argue that most group tasks can be classified in four categories: generate, choose, negotiate and execute. Subsequently, they distinguish eight task types varying on two continua that create a two-dimensional space. One continuum varies from cognitive to behavioural tasks, the other from cooperative tasks to those that generate conflict. Strauss (1999) tested the effect of three task types on interaction and reports that 'idea generation', 'intellective' and 'judgement tasks' appear to have a significant effect on the type and amount of 'approving', 'disagreeing' and 'procedural' statements. Agreement, disagreement, and process communication corresponded to the needs for member interdependence in group tasks.

Another distinction, more common to educational research, is that of concept-learning tasks (i.e. fact-based) and design tasks (i.e. analysis and synthesis). Concept-learning tasks can be seen as a '*well-structured tasks*' which often require the application of a limited number of rules or principles and have one correct solution, whereas design tasks can be regarded as '*ill-structured tasks*' which have a considerable degree of uncertainty regarding the rules and principles that can be applied and often have no clear-cut solution (depending on many variables in the problem space) (Jonassen, 1997). In principle, well-structured tasks will elicit less interaction because they aim for convergence, i.e. there is only one correct solution (Jonassen & Kwon, 2001).

Apparently different task types constitute a varying degree of interdependence (Illera, 2001) and thus are likely to invoke different interaction processes (e.g. tasks with a higher need to establish common ground are likely to lead to different interaction processes than a task that has a pre-defined solution path). Thus, a second critical element is constituted by task type, and can be depicted on a continuum ranging from '*well-structured tasks*' to '*ill-structured tasks*'.

5.3. Level of pre-structuring

The third dimension addresses the observation that collaboration sometimes develops spontaneously, but more often it does not. Therefore, a continuum is proposed that addresses the level to which interaction is pre-structured in advance by either teacher or designer, through either instruction or the technological environment to ensure positive interdependence and individual accountability. Examples are 'Group Investigation' (Sharan & Sharan, 1992), 'Student Teams Achievement Division' (Slavin, 1995), 'Jigsaw' (Aronson & Thibodeau, 1992; Bielaczycs, 2001), 'Structural approach' by Kagan (1994) (each structure is a scenario to teach specific skills and, although not likewise articulated, it is implicitly assumed that no situation is identical), 'Progressive Inquiry' (Rahikainen, Lallimo, & Hakkarainen, 2001), the use of scripts (O'Donnell, 1999; Weinberger, Fischer, & Mandl, 2001), scenarios that pre-scribe collaboration activity (Wessner, Pfister, & Miao, 1999), feedback rules or requirements of a minimum degree of contributions to a discussion (Harasim, 1993; Harasim, Hiltz, Teles, & Turoff, 1995). It is important to note that most procedures have been tested and applied in elementary or secondary settings, but they can be adapted to other levels of education (college and higher education) or CMC settings (Miyake, Masukawa, & Shirouzou, 2001; Strijbos & Martens, 2001).

Given the abundance of research on different methods (or structures) to support interaction, pre-structuring seems an important element for design of any CSGBL setting. An unresolved issue is when, how and what kind of pre-structuring is used to support interaction. Too much structure may result in 'forced' artificial interaction, but no structure may result in fragmented interaction or a situation where interaction could be seen as an optional activity instead of an essential process. These methods differ considerably in the extent to which interaction, or student activity, is prescribed. For instance, 'Jigsaw' elicits rather 'rigid' task division, whereas 'Progressive Inquiry' scarcely prescribes the level of task division. Thus, the continuum of the third dimension regarding the level of pre-structuring ranges from '*high pre-structuring*' to '*low pre-structuring*'.

In sum, it has been illustrated that all three elements can be represented as dimensions on a continuum with two poles: 'open skills' to 'closed skills', 'well-structured tasks' to 'ill-structured tasks' and 'high pre-structuring' to 'low pre-structuring'. Fig. 4 illustrates these three dimensions of CSGBL and depicts how, in general, settings that use 'Jigsaw' (J) and 'Progressive Inquiry' (PRI) are designed.

Although it can be argued that open skills are in general best served with ill-structured tasks (as are closed skills with well-structured tasks), and conclude that one dimension would suffice for this distinction, it is important to note that collaborative discovery learning (depicted by 'D') uses ill-structured tasks for the acquisition of closed skills with little pre-structuring (cf. De Jong & Van Joolingen, 1998). In the same sense, Structured Academic Controversy (depicted by 'SAC') uses well-structured tasks for the acquisition of open skills with a high level of pre-structuring (cf.

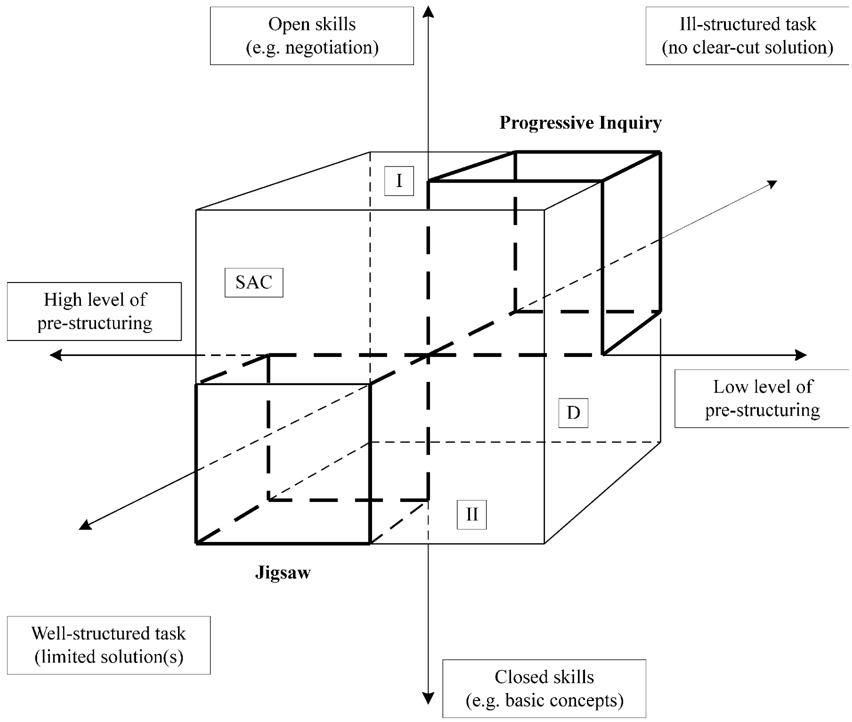


Fig. 4. Three dimensions of CSGBL.

Johnson et al., 1992). Thus, distinguishing both dimensions does not complicate the model unnecessarily; rather a multidimensional representation transcends the enduring polarisation of a uni-dimensional 'cooperative/collaborative' distinction and reveals CSGBL design possibilities (roman numerals) that previously were not readily considered due to paradigmatic constraints. Moreover, the position on the three continua may explain interactions and outcomes that previously were hard to interpret. Apart from these three key elements, two additional elements can be identified that appear essential for the design of group-based learning: 'group size' and 'computer support'.

5.4. Group size

As group size increases, group performance effectiveness depends, on the one hand, on the group's use of increased resources and opinions and on the handling of increased coordination and group management processes on the other (Shaw, 1981; Saavedra, Earley, & VanDyne, 1993). In CSGBL settings, research that compares different group sizes and their effect on interaction is rare. In theory, however, differences can be expected between a dyad that collaborates for thirty minutes on a task and a group of four students collaborating for thirty minutes on the same task. Given the time constraint, students in dyads can make more contributions than students in a four-person group. Moreover, if a CSGBL setting aims at knowledge co-construction, it is important to note that not only does a two-, three- or four-person group differ in the number of alternative opinions, but that at the same time a larger group requires more effort from group members to achieve common ground or a problem solving approach. Hence, in some cases research results obtained with dyadic interaction cannot be readily transferred to other group size constellations.

Although publications often make no explicit distinction between dyads (two members), small groups (three to six members) and large groups (seven or more), there are indications that group size is related to different interaction patterns or learning benefits, especially if participation equality or shared products are required. Fuchs et al. (2000) compared dyadic and four-member groups and observed that four-member group compositions elicited more cognitive conflict (disagreement and negotiation) than dyads, and appeared better suited for average and high-achieving students. A non-significant trend was observed favouring dyads with respect to participation equality, especially in favour of low-achieving students. Fuchs et al. further argue that group size likely affects equality of interaction and contribution to a shared product. Another example is that of Veerman and Veldhuis-Diermanse (2001) who observed, in a higher education setting, a more intensive discussion flow in three-member groups compared to dyads. But they also note that it is not "(...) fruitful to discuss 'ideal group size' in relation to knowledge construction; i.e. the impact of group size is relative. Among other factors this depends on how group communication is organised, how the task is designed and what tools are available" (p. 630–631).

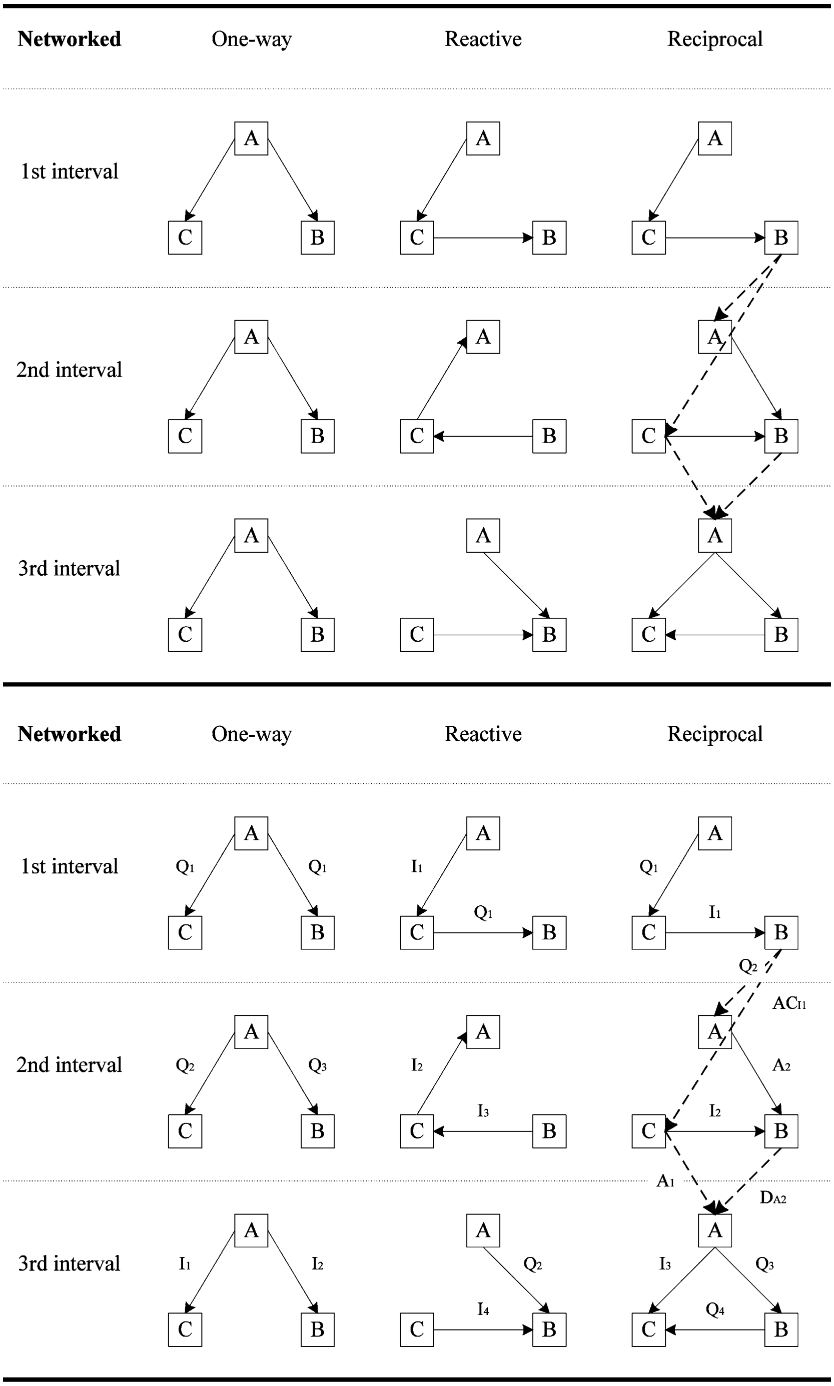
The typology of dyadic communication, discussed by Rafaeli and Sudweeks (1997), can be extended to networked interaction in small groups of students (three to six members). In concordance with the dyadic typology, three representations can be conceptualised. The first pattern represents interaction dominated by one student. In the second pattern all group members participate, but do not build on each other's contributions. The third pattern represents interaction that is spread across episodes, and messages build on the input of preceding messages. Fig. 5 is a further modification of Rafaeli and Sudweeks's representation of dyadic interaction and provides a conceptualisation of small group interaction on levels two and three (see also Sections 3.2 and 3.3).

Interaction in large groups can be more effectively conceptualised as a collection of dyadic and/or networked interaction. In large groups (seven or more members) students are less likely to affect all other members (Forsyth, 1990). Rogoff (1995), moreover, argues that studying interaction in learning communities or large groups ('participatory appropriation') requires that interaction on other planes of activity, i.e. in dyads or small groups, is kept in mind. Thus, interaction in large groups does not constitute a separate category.

In sum, although the few studies reported are too premature for a conclusion regarding the impact of group size on interaction, they point out that group size is an aspect of CSGBL that needs additional research (Gros, 2001) and must be considered with respect to expected interaction and CSGBL design.

5.5. Computer support

Regarding the role of computer support technology, it is most often the distinction between effects *with* and *of* technology that is emphasised (Salomon, Perkins, & Globerson, 1991). Lipponen (2001) argues that such an awareness of technology use should be extended to CSGBL: effects *with* and *of* CSGBL; and introduces another distinction, namely between 'collaborative use of technology' and 'collaborative technology'. Collaborative use of technology refers to generic



Q = question, A = answer, I = information, AC = acknowledge, D = decline

Fig. 5. Typology of level two and three interaction (networked).

technology that supports (one or more) basic aspects of communication, collaboration and coordination (e.g. 'Learning Space', 'Blackboard', 'WebCT' or 'Firstclass'). Collaborative technology, on the other hand, refers to dedicated tools designed to provide specific support: dialogue structuring (C-CHENE) (Baker & Lund, 1997), diagrammatic representations (Belvedere) (Suthers, 1999), thinking types (CSILE; Knowledge Forum) (Scardamalia & Bereiter, 1991), anchoring through writing or discussion prompts (CaMILE) (Guzdial & Turns, 2000), or perspectives to represent information in a communal database (e.g. individual, team, class or comparison) (Webguide) (Stahl, 2001). A third important aspect that needs to be considered is how technology is used during interaction. Crook (1998) makes a distinction between interaction *with* computers, interaction *at* computers and interaction *through* computers. Interaction *with* computers refers to individual student interaction with a computer simulation or tutoring system, and will not be discussed further. Interaction *at* computers represents a group of students interacting with a computer program or tutorial and can be either face-to-face (F2F) or computer-mediated. Interaction *through* computers refers to interaction between group members via networked computers, i.e. group members are not present in the same place (e.g. e-mail, newsgroups, chat, Knowledge Forum, etc.).

It is only reasonable to assume that interaction through computers should only be used when it is relevant. However, many research reports indicate a lack of student participation in electronic discussion forums in formal educational settings (Guzdial & Turns, 2000; Lehtinen, Nurmela, & Salo, 2001). It is very likely too that in some evaluations, where it was concluded that (computer) technology did not elicit the expected interaction, this was actually caused by the design of the CSGBL setting. Oliver and Omari (2001) conclude that lack of student appreciation might be stimulated through further development of the web-based system, but a higher level of pre-structuring may equally likely elevate appreciation. Veerman (2000) concludes from several observations that the task, rather than the technological tool provided, affects discourse and interaction.

In sum, computer systems should be supportive of the needs of students in a group-learning situation (Jeong & Chi, 1997) and not all CMC tools provide the same opportunities for interaction (Chin & Carroll, 2000). Moreover, the fact that something is technologically possible does not imply that it is also educationally desirable (Salomon, 2000). Designers should not be lured in thinking that students use technological support exactly in the way intended (Martens, 1998). Thus, "whether the opportunities are actually taken and whether taking them upgrades performance and leaves some desired cognitive residue, is less dependent on the technology and far more on other factors." (Salomon, 1992, p. 63).

6. Designing for interaction: a process-oriented methodology

In the introduction to this article, a need for a more systematic approach to CSGBL design was identified. The proposed process-oriented design methodology implies that a conceptualisation of the expected interaction is made explicit in advance and stresses the identification of critical elements that affect the interaction. Based on a literature review, five critical elements have been identified: learning objectives, task type, level of pre-structuring, group size and technology. We recommend that the design of any CSGBL setting starts with a conceptualisation of the expected (type of) interaction or changes in interaction due to pedagogical or technological tools. Subsequently, the chosen type of learning objectives, task type, level of pre-structuring, group size and computer support, deemed to elicit the expected interaction, need to be specified, and the CSGBL setting designed accordingly.

6.1. Six steps to designing CSGBL: application and limitations

The process-oriented design methodology for CSGBL settings consists of six steps. The design of *any* CSGBL setting starts with determining the learning objective because the expected interaction, seen as best suited to support the chosen learning objective, varies. Since a process-oriented design requires that the expected interaction is specified in advance, the first two steps are performed simultaneously. The six design steps are: (1) determine the learning objectives, (2) determine the expected (changes in) interaction, (3) select the task type, (4) determine whether and how much pre-structuring is needed, (5) determine group size, and (6) determine how computer support can be applied to support CSGBL. A list of questions has been compiled (Table 1) to assist CSGBL design from a process-oriented perspective.

During the (re)design a teacher/designer is asked to determine the learning objectives and to specify the interaction process (and/or possible changes in interaction processes) that is considered most supportive to enable students to attain the learning objectives, according to the three levels of interaction. They have to indicate, in advance, how (changes regarding) key elements (for instance a different pedagogical approach) affect interaction, thus making it possible to assess afterwards whether the expected interaction (or changes) did occur. More importantly, differences regarding learning outcomes can be related to observed changes in interaction processes.

Although teachers/designers often prefer a clear set of design rules, a checklist with limited categories is a bridge too far, especially since CSGBL requires a probabilistic design view rather than a causal view. Therefore, a designer has to constantly review whether the critical element will elicit the expected (changes in) interaction. Therefore, each step implies that previous decisions are taken into account.

7. Discussion

Currently, the design of CSGBL settings is commonly motivated with concepts such as 'cooperative' versus 'collaborative', or 'positive interdependence' and 'individual accountability'. A critical review reveals that neither are substantial enough to serve as a basis for the design of a CSGBL setting. In addition, research results show large variations regarding the relationship between interaction and learning outcomes, caused by differences in length of study, technology used, group size, research methodology and unit of analysis (Lipponen, 2001). Developers question what tasks or work methods should be used (Enkenberg, 2001) and express the need for a more systematic approach to CSGBL design (Gros, 2001).

In this article the framework for a process-oriented methodology for the design of CSGBL is proposed. This methodology is grounded on a probabilistic view on design, manifested through its focus on interaction processes rather than static learning outcomes. This implies a clear conceptualisation of interaction and that the expected interaction, or changes due to re-design, can

Table 1
Six steps when designing computer-supported group-based learning

1. Determine which type learning objective will be taught:
(1) What type of skills will be taught?
Open skills: argumentation, negotiation, discussion of multiple alternatives
Closed skills: acquisition of basic skills, basic procedures (long division), concept learning
(2) Are all students required to learn the same skill(s)?
(3) Must all students individually display mastery of the learning objectives?
2. Determine the expected interaction:
(4) Specify the expected interaction according to three levels if applicable.
(5) Will the interaction focus on feedback (e.g. commenting draft/final version)?
(6) Will the interaction focus on exchanging (or creating) ideas (or findings)?
(7) Will the interaction focus on discussion, argumentation of multiple alternatives/opinions?
(8) Does interaction require co-ordination of activities whilst solving a complex problem?
(9) Does interaction require a collaboratively written report representing shared understanding?
3. Select task-type with respect to the learning objective and expected interaction:
(10) Which task-type is best suited for teaching the selected skills?
Open skills: ill-structured task with no clear solution, multiple alternatives, outcomes, opinions or procedures
Closed skills: well-structured task with (few) one possible solution(s) outcome(s) or procedure(s)
(11) Are all students required to study the same material?
(12) Will they have to solve a complex and ambiguous problem with no clear solution?
(13) Will the chosen learning objectives and task-type require communication?
(14) Will the chosen learning objectives and task-type require co-ordination?
4. Determine whether and how much structure is necessary with respect to learning objective, expected interaction and task-type:
(15) Determine to what extent the group interaction processes will be pre-structured in advance?
High level of pre-structuring: student interaction is prescribed by the teacher (giving or receiving feedback, suggestions or help), content focussed (content-based roles, resource interdependence)
Low level of pre-structuring: students shape their groups' interaction processes with little or no teacher involvement (knowledge building, case based discussion of multiple alternative solutions, problem based learning)
(16) Are students each assigned to a portion of the material?
(17) Are students each assigned individual responsibilities for interaction and group performance?
(18) Are students dependent on each other during the whole course or only a part of the course?
(19) How will the students be graded: individual test-scores, one group-score for the group's performance, individual-score for each members' participation and contribution, or a combination?
5. Determine which group size is best suited with respect to learning objective, expected interaction, task type and level of pre-structuring:
(20) Is interaction with other group members obligatory ('positive interdependence') or optional?
(21) Is there a set minimum for group interaction participation (e.g. discussion entries)?
(22) Is the effort of all group members needed to achieve the learning objectives?
(23) Is the interaction focus on feedback (dyads preferred), idea generation (large group preferred) or consensus generation and negotiation (small group preferred)?
(24) Will all members have to contribute equally?
(25) Is there a need for diversity in opinion (discussion) or more focus on exchange of ideas (feedback)?
6. Determine how computer support is best used to support learning and expected interaction:
(26) How are students supposed to 'collaborate': at a computer or via computers?
(27) Will Communication be mainly face-to-face, computer mediated (CMC) or a combination?
Is student interaction same time/ same place (face-to-face: with and at computer)?
Is student interaction same time/different place (synchronous CMC)?
Is student interaction different time/different place (asynchronous CMC)?
(28) What kind of support is required: file sharing, communication, or a combination?
(29) Which tool e.g. newsgroup, groupware or chat supports the group-based learning setting best?

be specified a priori. Since we argue that interaction is the core of any CSGBL setting, design should focus upon critical elements that affect interaction. Five critical elements were identified and their relationship with the expected interaction was discussed. Although most teachers and developers would prefer a clear set of design rules, CSGBL design depends on how learning objectives, task type, level of pre-structuring, group size and type of computer support affect the expected interaction specified a priori. As Sorenson (1971) argues: "(...) prediction of group performance qualities on the basis of task demands is not likely to have much success until research has mapped more explicitly the relationships between demands, behaviour and performance" (p. 493).

Some critical remarks about the proposed methodology can be made. First of all, it is based on literature analysis, often hindered by vague definitions used to describe design of CSGBL settings. Presently, there is no empirical evidence that the proposed design methodology provides better support for CSGBL design. Secondly, it is unrealistic to assume that the methodology provides a full guarantee that the expected interaction will be observed. CSGBL "describes a *situation* in which particular forms of interaction among people are expected to occur (...) but there is no guarantee that the expected interaction will occur" (Dillenbourg, 1999, p. 5). Based on a probabilistic view on the design of CSGBL, however, a process-based methodology increases the likelihood that the expected interaction can be observed. Finally, it would be utopian to expect that a group's total interaction can be summarised through one of the prototypical interaction levels. Similarly, it can be questioned whether it is (a) feasible to fully prescribe the expected interaction in view of 'self-regulated learning' and (b) probable to exert full control over *a group as a learning environment*. However, the learning objectives, task type, level of pre-structure, group size and computer support (or changes) can trigger changes in part of the total interaction. In addition, CSGBL settings sometimes consist of different tasks that each can elicit different interaction (e.g. tutoring, brainstorm, discussion of information), or specific goals can be characterised by specific interaction processes (Suh, 2001). In other words, depending on the design, several types of interaction may occur, thus emphasising that designers should be aware which type of interaction is expected at a given state in a CSGBL design.

A future development of this methodology could be to apply this methodology as a yardstick for good practice, where good practice is defined as the extent to which CSGBL designs specify (changes in) expected interaction in advance and whether it elicited the expected interaction. At present, there is "(...) little descriptive dynamic data on the complexity of the process and how it might be affected by combinations of task, people, and technology attributes." (Guastello, 2000, p. 174)., There is, however, a good indication that technology can assist to extract interaction patterns, for instance by using a computer tool to construct SNA networks of student communication (interaction on level one) (Ou, Wang, Chen, & Chen, 2001). Another approach may be a theory-based interaction analysis system to guide CSGBL design (Inaba et al., 2001). Nevertheless, it can be questioned whether 'theoretical' approaches can account for variations in group interaction (see Section 4 of this article). Some theoretical approaches may elicit similar interaction patterns, thus making it difficult to use these to guide CSGBL design. Finally, technology may be used to assess effective interaction patterns and eventually design intelligent agents that can guide interaction (Soller, 2002).

In sum, the process-oriented methodology outlined can stimulate designers (a) to adopt a more systematic approach to CSGBL design, (b) to design CSGBL according to the expected interaction while paying attention to critical elements that affect the interaction, (c) to bridge the gap between the quality of observed interaction and learning outcomes, (d) to stimulate cooperation between instructional design and CSGBL research and (e) to further CSGBL design that focuses on the heart of the matter: interaction.

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