# Negotiating About Shared Knowledge in a Cooperative Learning Environment

**Hans-Rüdiger Pfister, Martin Wessner, Torsten Holmer, Ralf Steinmetz**

GMD — German National Research Center for Information Technology, Integrated Publication and Information Systems Institute (IPSI)

Abstract: A goal of cooperative learning is the construction of shared knowledge. Shared knowledge represents the common understanding of a group of individuals with respect to the content domain; the active construction of shared knowledge enhances acquisition and retention. Two requirements have to be met during the construction process: First, shared knowledge should be represented explicitely; second, the participants' multiple perspectives need to be integrated. We focus on the second aspect, called knowledge negotiation, by which the learners' common understanding is construed. However, common understanding comes in degrees. We provide a theoretical perspective for the negotiation process and propose a quantification of shared knowledge, called the degree of agreement (*degreement*). Finally, we discuss how a learning environment for distributed learners can support the process of cooperative knowledge construction.

Keywords: cooperative learning, shared knowledge, multiple perspectives, degreement

**Introduction**

Cooperative learning, as opposed to individual learning, has many advantageous properties (Koschman, 1996; Slavin, 1995). Nowadays, it is possible that, given access to the Internet, anybody can cooperate with anybody anywhere; we call this kind of learning "Distributed Computer Supported Cooperative Learning" (D-CSCL). In this paper, we focus on self-organised learning. In guided learning, knowledge is distributed by a knowing resource (teacher), it is represented in the form of well-prepared material (books, scripts), and it is normally accepted as valid. However, in self-organised learning, (a) there is no omniscient teacher, but participants with different degrees and areas of expertise, (b) materials are not well-structured, and (c) acquisition proceeds mainly by discussion. Imagine, e.g., a group of programmers learning cooperatively a new programming language. Here, learning can be understood as exchange, (re)construction, and negotiation of multiple perspectives, rather than as delivery of information. The goal is to establish a sufficient amount of shared knowledge from the participants' multiple perspectives.

## Distributed and shared knowledge

The notion of distributed cognition has been advanced, among others, by Salomon (1993). It refers to the observation that much of the "intelligence" needed to solve a problem is not inside individual minds, but is distributed across different persons as well as embodied in external artifacts. Situational affordances, rather than individual symbolic representations, regulate the cooperative activity of intelligent action. Similarly, we think of distributed cooperative learning as an activity that transfers knowledge from many sources and yields a corpus of socially shared knowledge.

For simplicity, we assume that knowledge can be described as a collection of *facts* (Nickerson, 1993); we use the term "fact" generically, including rules etc.. Each learner "owns" a set of facts (i.e., holds as set of beliefs) with respect to a specific domain. Cooperative learning can be construed as the exchange of facts among multiple learners, especially from knowing to ignorant learners.

With this simplified model, the notions of distributed and shared knowledge are defined as follows. Given a group of n persons, with each person i owning a set of facts $F_i$ , *shared knowledge* is the intersection $\leftrightarrow F_n$ of all sets $F_{i..n}$; i.e., shared knowledge is knowledge all persons have in common. For distributed knowledge, we introduce the notion of *task relevant* knowledge: given a task T, $F_T$ is a set of facts sufficient to solve T. Hence, knowledge to solve a task is *distributed* if the set $F_T$ is not exclusively owned by a single person.

## Knowledge negotiation

During learning, a person has to accept the facts delivered by another person. However, a student might not immediately accept a fact delivered by the teacher. Knowledge is usually not just transferred, but actively construed and expanded during learning, as Pea (1996) emphasizes in his transformative communication approach. Hence, after negotiation, there are four alternatives: (a) the student eventually accepts the fact as part of his knowledge, (b) s/he rejects the fact, (c) s/he is undecided, or (d) student and teacher agree on a new fact as a result of the negotiation process.

Generally, it is not a single fact that is negotiated, but a composite of several facts pertaining to a topic. We call such a composite a *perspective*, and multiple learners normally have multiple perspectives. For example, a group of students wants to learn how to interpret an experimental finding, and they consult an expert. The expert proposes an interpretation consisting of four facts (facts 3 to 6 in Table 1). Student A’s perspective consists of three facts, two of which are different from the expert’s perspective; student B’s perspective is based on only one fact.

Table 1 Distribution of facts across learners

| | fact 1 | fact 2 | fact 3 | fact 4 | fact 5 | fact 6 |
|---|---|---|---|---|---|---|
| Student A | x | x | | x | | |
| Student B | | x | | | | |
| Expert C | | | x | x | x | x |

Learning from the expert means to accept his and discard one's own facts; e.g., student A should accept facts 3, 5, and 6 and discard facts 1 and 2. Of course, we do not argue that students be uncritical and should directly accept the expert's authority. They should discuss why her or his perspective is more appropriate (or not), and evaluate arguments which (dis)confirm it. Metaphorically speaking, active learning is like negotiating: for example, two parties start negotiating about the price of a car, each announces a starting offer, they exchange new offers, some threats, and eventually settle on a final price, or they part without agreement (Raiffa, 1982). Instead of starting offers, multiple perspectives are debated during cooperative learning; instead of threats, arguments are exchanged; instead of a final price, shared knowledge is achieved.

**Degreement: A measure of shared knowledge**

Just as a price moves between two extremes, agreement on shared knowledge moves between total disagreement and total agreement. The degree of agreement, called *degreement* for short, constitutes a quantitative measure, ranging from —1 (total disagreement) to +1 (total agreement). Qualitatively, it represents the topic of degreement, and which of the topic's aspects (facts) one agrees or disagrees upon. We conceptualise degreement as a relation between persons, specifically, as the degree of similarity between the knowledge $F_i$ and $F_j$ two persons i and j own with respect to a given topic. We presume that an explicit representation of degreement supports active learning.

Degreement, in addition to being a quantitative measure, is a function of the facts learners agree upon as well as of the facts they disagree upon. Furthermore, degreement is an asymmetric function, i.e., the degree with which I accept somebody's knowledge is not necessarily mirrored by the degree with which s/he accepts my knowledge. Tversky (1977) has proposed a measure of similarity which provides a suitable starting point. The idea is to define the similarity S between two objects A and B, represented as sets of features, as a function of the ratio of common and distinctive features:

$$S(A,B) = f(A \cap B) \,/\, \alpha f(A-B) + \beta f(B-A) + f(A \cap B); \qquad (1)$$

with $A \cap B$ being the intersection, A-B (B-A) the distinctive set of features of A (of B), f a nonnegative function, and $\alpha$ , $\beta$ parameters ($0 \leq \alpha , \beta \leq 1$), which determine the symmetry of S. S ranges from 0 (no features in common) to +1 (all features in common).

As a *measure of degreeement* (D), we propose a slightly modified version:

$$D(A,B) = (|A \cap B| - |A-B| - |B-A|) / |A \cup B|; \qquad (2)$$

with $A \cup B$ being the union of A and B, and $|A|$ the number of elements in A, which redefines the range from total disagreement (-1) to medium (0) to total agreement (+1).

The degreement D between two persons A and B is measured as the Tversky-similarity between their two sets of facts. Psychologically, it seems plausible to make a difference between essentially opposed perspectives ($D < 1$), and perspectives which are consensual ($D > 0$). So far we do not distinguish between a belief that a fact is true, a belief that a fact is not true, and indifference towards a fact. D can in principle be extended to represent degreement among multiple persons.

Note that this conceptualisation does not directly operationalise how degreement is assessed. It might be difficult to separate discrete facts and align persons and facts according to their common and distinctive knowledge. Hence, as an approximation, degreement is indirectly measured, using rating scales or voting schemes.

In guided learning settings, using the asymmetric variant, learning can now be understood as the process of maximising degreement from the teacher's point of view. In self-organised settings, the symmetrical variant seems more appropriate. Here, learning means to maximise shared knowledge as measured by symmetrical degreement.

## Computer support for knowledge negotiation

Computer-supported learning enables learners to communicate in ways which are not possible in face-to-face interaction. For example, transfer of knowledge can switch from synchronous to asynchronous modes, or any mixtures inbetween. Some aspects of negotiation can be hidden, for example, anonymous voting to assess degreement. Shared knowledge can be represented as a common view, and descriptive measures such as degreement can than be computed automatically. In this section, we briefly describe how degreement is dealt with in a learning environment called CROCODILE, currently under development at GMD-IPSI (Pfister et al., 1998).

### Explicit representation in a learning net

The CROCODILE system has two layers for representing content: one is a hypermedia document structure, where text, graphics, and other content objects are generated and linked. A second layer, called a learning net, represents the main topics of the domain as a graph structure consisting of nodes and edges (Pfister et al., 1999). Each node, in turn, refers to a document where the content of that node is stored, or to a person, who is a kind of expert with respect to the node content. The learning net serves as a representation of shared knowledge in several ways: (i) degreement is indicated by different colors of the nodes, (ii) degreement of each node can be viewed and assessed, (iii) there is a choice of several methods to assess degreement and to define default values (e.g., a degreement threshold value for deleting nodes). Exploring the learning net, learners get an overview of the content under discussion as well as information on topics with multiple perspectives, i.e., where little degreement exists.

### Negotiation support with learning protocols

The CROCODILE system also provides a number of so-called learning protocols (Wessner et al., in press). Each learning protocol systematically guides a special kind of communication or cooperation activity. For example, the explanation protocol controls a dyadic explanation process by systematically switching roles (explainer and explainee), providing a specialised interface to enter explanations and questions and for storing the dialogue for future use. Similarly, degreement protocols support the process of degreement measurement, i.e., they prompt the user to assess degreement, and they compute various degreement measures (e.g., symmetric and asymmetric).

**Discussion**

In sum, learning as a self-organised cooperative process in a distributed environment is a complex process of negotiation, aiming at the construction of shared knowledge. A computerised learning environment can support this process by providing an explicit representation of shared knowledge, by providing a measure of the degree of agreement on the topic under discussion, and by supporting the process of degreement assessment. In CROCODILE, we aim at supporting all of these aspects. Currently, we are exploring how to assess and represent degreement appropriately, and we are empirically testing whether and how negotiating knowledge with CROCODILE improves cooperative learning processes of distributed learners.

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**Authors' addresses**

*Hans-Rüdiger Pfister (pfister@darmstadt.gmd.de), Martin Wessner (wessner@darmstadt.gmd.de), Torsten Holmer (holmer@darmstadt.gmd.de)*
*GMD — German National Research Center for Information Technology, Integrated Publication and Information Systems Institute (IPSI); Dolivostr. 15; 64285 Darmstadt; Germany. Tel. ++49 (0)6151 869 947. Fax ++49 (0)6151 869 963.*