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Essay review

Computer supported collaborative learning

Computer supported collaborative learning: cognitive and computational approaches. P. Dillenbourg (Ed.); Pergamon, Elsevier Science Ltd., Oxford, 1999, 246pp., ISBN 0-08-043073-2

Collaborative learning is a central concept in modern theories of education. It fits in perfectly with the changing views on learning and on the nature of knowledge acquisition. Unlike in the past, it is considered wise to give the learner a more active and more constructive role. Moreover, this knowledge-constructing process is not merely looked upon as an individual affair but rather as a process of interaction and negotiation with other agents in the learning environment such as the teacher, fellow students and the teaching materials. In this view it is emphasized that knowledge is no longer to be thought of as absolute, tied to a single person, but rather as relative to a community of learners (Linden, van der Erkens, Schmidt, & Renshaw, 2000).

The advent of widespread Internet access and technological advances that provide higher bandwidth and powerful software tools has promoted a new impetus to research in this area. New technology has expanded the concept of collaboration to include, for instance, long-distance collaboration (via the Internet) and computer-supported collaboration, running the gamut from simple programs merely enabling communication, to systems aiding students singly, to systems enabling an entire classroom collaboratively to build their own knowledge base.

1. Collaborative learning in students and computers: a unique cross-fertilization project

This article is an essay review of a book that is the result of a series of workshops which provided a setting in which researchers from cognitive psychology and machine-learning computer science were encouraged to discuss their different approaches to collaborative learning. Most chapters in the book have been co-authored by scholars from both sides. Their approaches are rather divergent, and attempts to find a common ground have led to interesting, but rather theoretical discussions. Authors try to compare the various approaches or try to apply theoretical notions or methods of analysis across the fields. The contributions show great variation in level of detail and quality, which nevertheless form a collection of challenging ideas and interesting efforts at integration. Naturally, one needs to have modest expectations about the outcome of such a first effort of cross-fertilization of two disciplines that have not regularly collaborated. If the reader expects a final, integrated, consistent view on collaborative learning in educational practice, he or she will be disappointed and may well end up confused about the differences in viewpoints and assumptions to which the authors adhere. If, however, the reader expects to get an impression of recent developments and of current discussions on this theme, this expectation will be satisfied. Furthermore, the reader will be inspired by the theoretical emphasis and by the enthusiasm with which the disciplinary boundaries are explored and crossed. However, for the most part, the larger educational practice is not taken into account in the book. In the context of the larger educational practice, teachers are confronted by multiple groups of collaborative learners, technological support issues, organizational aspects, parents, the influence of the community, etc., in addition to changes in instructional practice and curricula. It is the view of collaboration in this larger educational context that we will first discuss briefly.

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2. Collaborative learning has an important place in new learning theories

Littleton and Hakkinen (Chapter 2) point out that many researchers have recognized the importance of collaborative learning. They mention that Piaget, for instance, emphasized social interaction, and more specifically peer interaction, from the perspective of its specific role in the development of logical reasoning. Vygotsky (1978) went even further by conceptualizing social interaction as being at the core of the developmental process. In new learning theories, collaboration again takes an important place. These theories have spawned a changing view on learning and instruction. Constructivism and all it implies is perhaps the most important one.

Constructivism is not a single concept, but can involve the following three aspects (Kanselaar, Jong de, Andriessen, & Goodyear, 2000):

1. a set of epistemological beliefs (that is, beliefs about the nature of reality, whether there is an independent reality);
2. a set of psychological beliefs about the nature of mind, cognition and learning (e.g., that learning involves constructing one's own knowledge); and
3. a set of educational beliefs about the best way to support learning (e.g., that direct instruction through lecture methods is very limited or inappropriate; that knowledge emerges from constructive interaction between the teacher and the student or between collaborating students; that ne should allow learners to define their own learning objectives; and that engaging materials, such as dramatic video cases are potentially very valuable).

This point of view has consequences for education not covered in the book, e.g., the work of Marlene Scardamalia and Carl Bereiter in Toronto. Constructivism is the main theoretical base for the pioneering work of these researchers, who built their efforts in computer-supported collaborative learning (CSCL) upon a compelling vision of educational reform: students as members of knowledge-building communities (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). They and their colleagues developed computer-supported intentional learning environments (CSILE) as environments in which students might build knowledge for the sake of developing their community's understanding, in the same way that scientists publish research papers for the sake of advancing the research community's understanding (Scardamalia, Bereiter, & Lamon, 1994; Guzdial, 1997). Despite the success of Scardamalia and Bereiter, the path from current practice to knowledge-building community is a challenging one. Still, we believe that CSCL can serve to further the goals of educational reform. The biggest challenge is getting teachers and students to buy in: to get teachers to put effort and value into CSCL, and to get students to want to participate.

Applying constructivism results in essential changes in curriculum and instruction. The difference between traditional curriculum and instruction and knowledge-building communities may seem subtle at first. The two have in common the goal of student learning that can be assessed in traditional tests, and CSILE research indicates that students in a knowledge-building community will perform as well as or better than students in traditional classrooms on standardized tests (Scardamalia et al., 1994). Yet, the knowledge-building community is not merely a *platform* for the delivery of curriculum. It is a fundamentally different approach to learning that breaks down the artificial separation between curriculum and instruction. Curriculum and instruction become subsumed in the practice of creating a knowledge-building community. Knowledge-building communities therefore change the teacher's relationship to curriculum in several fundamental ways.

The application of CSCL environments also introduces a number of changes in the way students interact with teachers and peers. In contrast to face-to-face collaboration, students are required to put their thoughts in writing. This leads to more reflection on the subject and a deeper involvement in the particular subject. The results of these processes are permanently recorded in the environment. Students and teachers can access these products of discussion and articulation at any time.

The researchers of the knowledge-building communities project have noted at least four ways that the notion of curriculum has changed for the participants (Resta, Christal, Femeding & Puthoff, 1999). They say:

> First, curriculum becomes for the teacher less a plan for achieving predetermined outcomes and more an environment designed to enable knowledge creation in a specified arena of discourse. Second, curriculum has less of a focus on subject matter or content and more on an environment designed around themes, projects, or problem solving. Third, use of curriculum designed by outside specialists diminishes, as curriculum designed through collaborative brainstorming between members of the learning community, including teachers and students, becomes commonplace. Finally, rather than falling into a fixed set of desired learning outcomes that requires considerable effort to change (usually by outside experts), researchers have found that teachers are continually revising their curriculum design based on their on-going experience and emergent instructional needs (p. 492).

3. 'Collaboration' is not easy to define

The terms 'collaborative' and 'collaborative learning' occur quite often in the above paragraphs. 'Collaborative', however, is shown in the book not to have a single, simple definition. The broadest (but unsatisfactory) definition of 'collaborative learning' is that it is a situation in which two or more people learn or attempt to learn something together. In the book, Dillenbourg indicates the following four defining aspects of the adjective 'collaborative':

1. A situation can be characterized as more or less collaborative (e.g., collaboration is more likely to occur between people of a similar status than between a boss and his/her employee, or between a teacher and a pupil).
2. The interactions that do take place between the group members can be more or less collaborative (e.g., negotiation has a stronger collaborative flavor than giving instructions).
3. Some learning processes are more intrinsically collaborative (e.g., grounding (see below) has a stronger collaborative flavor than induction), even if, at a very fine level of analysis, learning processes must be similar to those triggered in individual learning.
4. The fourth element concerns the effects of collaborative learning, not because this element is used to define collaboration itself, but because the divergent views concerning how to measure the effects of collaborative learning participate in the terminological wilderness of this field. (Dillenbourg, Chapter 1, p. 9)

We would, partly on the basis of the chapters, add the following three items that play a part in defining collaboration:

1. Different task aspects can influence the degree of collaboration (e.g., a task which can be easily broken up into single-student subtasks will be more cooperative, a task requiring the expertise of all the students will be more collaborative; having a common goal and complementary skills and knowledge will induce more or better collaboration (Erkens, 1997)).
2. Tools mediating the collaboration can induce or guide the interaction to be more or less collaborative (e.g., offering students different information, all of which is required to do the task, will induce more collaboration than all students having the same knowledge; computer support of discussion skills will increase the effectiveness of the collaboration).
3. Characteristics of the collaborators can influence the type and quality of the collaboration (e.g., a small group collaborates easier than a large group; artificial agents collaborate on simple repeated tasks, while for students collaboration tends to pay off on complex, unique tasks; having intrinsic motivation generally leads to better results than providing extrinsic motivation).

In studies, all the above aspects differ, which makes them difficult to compare and generalize. A few collaborative learning processes that are relevant to teaching have gained prominence in the literature and are further examined in the book.

Such processes are those by which students obtain a common ground in collaborative learning, that is to say, generate a common frame of reference in order to coordinate their actions and the ways they explain their actions and proposals to each other. We will next focus on these two processes, grounding and explaining.

4. Learning processes in collaborative learning

4.1. Grounding and coordination in collaborative learning

Grounding (Baker, Hansen, Joiner, & Traum, Chapter 3) appears to be an elementary process in collaborative learning, essentially creating a common frame of reference. The concept of grounding was first proposed in the linguistic research of Clark and coworkers (Clark & Brennan, 1991; Clark & Schaefer, 1987). In general, two principles are stressed in grounding research: minimal grounding is a prerequisite for communication to occur; and grounding signals are often explicitly required by communication conventions, frequently taking the form of acknowledgements or acceptances (head-nod, 'right', 'yes'). Grounding is rightfully part and parcel of the collaboration process because it plays a critical role in preventing misunderstanding and miscommunication. In collaboration using computer-mediated communication, nonverbal cues cannot be transmitted. Hence, we find that a substantial part of the effort in students' collaborative dialogues is centered on explicit verbal grounding: checking, supporting or discussing each other's understanding of the concepts involved (Veerman, in press).

In Chapter 3, Baker and colleagues analyze the concept of grounding in relation to the concept of appropriation as used in culture-historical activity theory. In this theory, based on the work of Vygotsky and Leontjev, learning is seen as a sociocultural activity where children appropriate culturally accumulated knowledge and tools. Appropriation takes place in interaction with other (adult) members of the culture when children participate in cultural practices using available tools. Language is seen as the most important tool mediating between thinking and activity. The relationship between grounding and appropriation that the authors suggest is that the learning occurring in collaborative situations may be associated with the increased effort associated with executing transitions between grounding and appropriation — in other words, between trying to understand each other and trying to understand the meanings of the language tools by which the interaction itself is mediated. Analyzing these relationships in collaborative learning situations, the authors posit that the goals of the students are crucial for such transitions to occur. Although we could not fully agree, this concept raises a new set of questions for us. For example, how may these goals of the individual students be influenced? How do task goals or the goals of the designers of the collaborative learning situation relate to personal goals? What is the role of the goals of the collaboration partner in this interaction? In short, what exactly motivates students to make this step from grounding to appropriation? From our own research (Erkens, 1997) we believe that the *need to coordinate activities*, in other words, to come to a *common* goal and a *common* task strategy, is crucial in trying to solve the collaborative task at hand. This coordination accounts for the difference between obtaining mutual understanding (I understand what you mean) versus obtaining a common understanding (I agree with what you mean). While mutual understanding can be seen as a prerequisite for communication and thus for collaboration, coordination of activities and agreement on a common line of reasoning is needed for a successful collaboration.

4.2. Explaining in collaborative learning

Explaining (Ploetzner, Dillenbourg, Preier, & Traurn, Chapter 6) is effective for both the explainer and the listener whether the explainer collaborates with himself or others. Though both have been shown to be very effective, the authors of Chapter 6, reviewing the literature, did not find any evidence that the interactivity of real explanation brings any extra benefit compared with self-explanation. Perhaps one can consider self-explanation and explanation to others as similar processes?

Of *explaining to oneself*, Dillenbourg mentions: "Although it may sound awkward to talk about 'collaboration with oneself', it is common to talk about 'conflict with oneself'. The idea that thinking can be viewed as a dialogue with oneself is not a new idea; it has been argued by Piaget, Mead and, of course, Vygotsky, for whom thought results from internalized dialogues." (Chapter 1, p. 4) Thus, while distributed cognition theorists treat the group as a single cognitive system, one may reciprocally view the individual as a distributed system (Minsky, 1987). Although mutual explanation, with same-level agents contributing equally, is the most pure form of collaboration, research on self-explanation or explanation to other-level agents is certainly informative. In a study on high-school physics, the better students performed more self-explanation in making sense of worked-out problem examples (Chi, Bassok, Lewis, Reiman, & Glaser, 1989). A follow-up study showed that when students were encouraged and structured to self-explain the examples by modeling, their results surpassed, across the board, those of students who simply read the to-be-learned material twice. In other words, they could be taught to be 'better students'. Impressively, the distance between the two groups increased as the type of question required more integration of the material (Chi, de Leeuw, Chiu, & La Vancher, 1994). Cognitive modeling of the self-explanation effect revealed that the most effective manner of self-explanation was to have the student explain each solution step provided within the examples, then identify missing knowledge and subsequently deductively or inductively construct the missing knowledge (VanLehn, Jones, & Chi, 1992). Research by others showed, however, that spending more time on explaining each solution step provides diminishing returns, tending to lead from insightful elaborations to paraphrasing or embellishing (Pirolli & Recker, 1994).

Explaining to others is used quite successfully in a teaching method called *reciprocal teaching*. One important finding of educational as well as psychological research is that students with deficient problem-solving and learning abilities frequently behave rather passively during instruction. If these students could be encouraged to participate actively in instruction, would their understanding improve? This question inspired Palincsar and Brown to develop this teaching method. An early study established that modeling of comprehension activities by an experienced tutor resulted in a gradual takeover of the skills by the student. At the end of a series of sessions, the student is able to behave much like the teacher in asking relevant comprehension questions, offering explanations, and engaging in negotiations (Palincsar & Brown, 1984). The effects of the intervention were shown to be durable and rather general, also extending to other coursework and silent self-study. Later studies extended this effect for trained student–untrained student modeling. Palinscar and Brown assume that two reasons are responsible for the success of reciprocal teaching: first, that it involves extensive modeling of the activities to be taught; and second, that it forces the student to actively locate comprehension failures, formulate questions, judge answers and construct explanations. Note that Chi's successful students already possessed these skills, demonstrated by their self-explanation success, and that in Chi's later study the modeled and taught self-explanation skills largely cover the same ground. Explanation skills appear to be excellent skills to apply in any collaborative situation, not just in comprehending material or doing physics.

5. Collaborative learning and computers

One of the intriguing aspects of this book is the broad range of views that the different scientific research areas present on the subject: the view of the learning group, the learning individual, the learning process, as well as the ergonomics and the simulations of cooperating robots. The result is a collection of contributions that provides a broad perspective on the different theoretical frameworks and methods used to explore collaborative learning.

5.1. Computers learning to collaborate

Why should we who are interested in human learning care about machine learning? Much of the

multi-agent machine-learning research described in various chapters is even carried out by simulated agents. Tasks that are carried out by these agents seem to be almost trivial, such as several simulated agents collaborating to find hidden items in a simple maze. A typical robot task involves collaboration to 'forage': find blocks and bring them to a specific area. Machine learning, however, is not bothered by what is simultaneously one of the most wonderful characteristics of humans and one of the most vexing characteristics for experimental research: the human knowledge store. For computerized agents, every bit of knowledge can be (and has to be) specified. Machine collaborative learning can inform students' collaborative learning precisely because interactions can be exactly specified and processes and outcomes exactly traced. But it can, at this time, handle only simple communication and simple knowledge bases. On the other hand, research on students' learning can inform machine learning of the many variables that still have to be investigated. As yet, the two disciplines appear to have quite a bit of ground to cover before they will meet.

5.2. Students learning to collaborate supported by the computer

In contrast to the simulation approach, the computer may also be used to mediate and/or support collaboration. In many contributions in the book tutorial support of collaborative learning is realized in an implicit way. Tutorial aspects of teaching collaborative learning are hidden in specific tools for communication (for example, scripted dialogue operators) or visualization of the learning environment (e.g., by supporting the construction of concept maps). In the chapter by Hoppe and Ploetzner (Chapter 8) an attempt is made to incorporate tutorial actions for collaborative learning into a computer-based environment. By modeling the state of the knowledge of individual students in the group, the computer tutor can construct interventions. Tutorial interventions include, for example, the formation of groups for specific learning purposes, the presentation of hints, or presenting adaptive problems to solve. This type of student modeling is a group-oriented extension of the traditional Intelligent Tutoring Systems approach, where only one student at a time is modeled. In our own current research (the COSAR project, see http://owkweb.fss.uu.nl/COSAR/), students use the computer both as a tool and as a support for project-based collaboration. Using the basic environment, already developed, two high-school juniors can collaboratively write an argumentative paper on-line while synchronously discussing the contents and extracting information from given sources. They can also take private notes. Mostly, the basic environment illustrates use of the computer as a tool: as a medium for communication, for presenting all writing real-time to both partners, and as a store for information. Though this is not normally considered a favorite task, students evaluated this format positively, calling it 'neat', 'different' and 'a good way to collaborate'. Clearly enjoying the task, they worked quietly and diligently. Next year we intend to extend the basic environment with three supports for planning the argument. Firstly, the *Diagrammer*, enabling a type of concept mapping, should aid planning the semantic organization of the paper. Second, the *Outliner* should aid linear organization of the text to be written. Third, we intend to develop an Advisor that will help the student to use the tools and to avoid common errors in writing such papers.

6. Conclusion: collaborative learning principles induce fundamental changes in teaching

Collaborative learning both with and without the computer will transform the practice of teaching. Traditionally, instructional practice, as the defining factor of a teacher's professional duty, requires that the teacher *locally implement* a curriculum, which has been determined outside the classroom. Curriculum is the *what* to teach. Instruction is the *how* to teach. The tacit assumption behind this division between curriculum and instruction is that knowledge can be specified in a decontextualized manner, and that prespecified knowledge will result from engaging in proper learning activities. In a collaborative, knowledge-building community, knowledge is constructed in

the context of pursuing higher learning goals. Teachers, often in collaboration with their students, design the higher level learning goals and a learning environment that supports the pursuit of those goals. The assumption now is that much of what has been the traditional curriculum may be encountered along the way, but those traditional learning outcomes are no longer prespecified in the traditional, externally specified and decontextualized sense of curriculum. Students encounter traditional facts on a need-to-know basis, where the need is determined by the requirements of the learning goal and not because the facts are in the curriculum and will be on the test.

The book under review illustrates the type of research needed to put a solid theoretical grounding underneath the concept of collaborative learning. Still, had the issues treated in the book been aimed more at a larger educational context, the book would have a greater appeal for teaching and teacher education.

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