In S. Vosniadou, E. De Corte & H. Mandl (1994) Technology-BAsed Learning Environments, pp.48-54. Berlin: Springer-Verlag.

Internalization and Learning Environments

Pierre Dillenbourg

TECFA**,** Faculté de Psychologie et des Sciences de l'Education, Université de Genève
9 route de Drize, CH1227 Carouge, Switzerland. E-mail: pdillen@divsun.unige.ch

Abstract. This contribution considers computer-based learning environments from a socio-cultural perspective. It relates the design of learning environments with the concept of internalization, i.e the genetic link between social speech, private speech and inner speech. We translate these levels in terms of user-system interactions and analyze the transition between levels.

Keywords. Collaboration, socio-cultural approach, distributed cognition.

1 Introduction

The socio-cultural approach postulates that when an individual participates in a social system, the culture of this social system and the tools used for communication, especially the language, shape the individual's cognition, and constitute a source of learning. Internalization is a central concept in this approach: "*Every function in the child's development appears twice: first, on the social level, and later on the individual level; first, between people (inter-psychological) and then inside the child (intra-psychological)*" (Vygotsky 1978). Internalization refers to the genetic link between the social (or inter-psychological) and the inner (or intra-psychological) planes. Inner speech is used to talk to ourselves, i.e to think. It has a function of self-regulation. In educational software, social speech refers to three kinds of interactions: (1) interaction between two human users on remote terminals or in front of the same terminal; (2) interaction between the user and the software designer, mediated by the tools included in the software which embody the designer's culture; and (3) interaction between the user and the system.We are concerned by the third form of interaction: when the learner interacts with a computerized agent performing a social role (e.g. a tutor), does this interaction have a potential for internalisation similar to human-human conversations (Salomon 1990)?

In the remainder of this chapter, we will refer frequently to two systems that we briefly describe now in order to make later references shorter. PEOPLE POWER (Dillenbourg and Self 1992) is a learning environment in which the human learner interacts with an artificial learning companion, hereafter referred to as the 'co-learner'. Its pedagogical goal is that the human learner discovers the mechanisms by which an electoral system is more or less proportional. The system includes a microworld in which the learner can design an electoral experiment (i.e. choose parties, candidates, laws, etc.), run the elections and analyze the results. The learners play a game in which the goal is to gain seats for one's own party. Both learners play for the same party. They engage in a dialogue to agree on a geographical organization of wards into constituencies. The co-learner has some naive knowledge to reason about elections. This knowledge is a set of rules (or arguments). For instance, a rule says "If a party gets more votes, then it will get more seats". This rule is naive but not basically wrong, it is only true in some circumstances. The co-learner learns how to apply this rule when it reasons about the way to gain seats for its party.

The goal of MEMOLAB is for psychology students to acquire the basic skills in the methodology of experimentation (Dillenbourg et al. 1993). The learner builds an experiment on human memory. A typical experiment involves two groups of subjects each encoding a list of words. The two lists are different and these differences have an impact on the recall performance. An experiment is described by assembling events on a workbench. Then, the system simulates the experiment. The learner can visualize the simulation results and perform an analysis of variance. MEMOLAB includes computational agents (coach, tutors and experts) that provide guidance during problem solving activities.

2 Distributed Cognition

To translate in computational terms the relationship between inner speech and social speech, we use the following metaphor: *view a human-computer pair (or any other pair) involved in shared problem solving as a single cognitive system.* Many designers conceive an ILE as a multi-agent system. Similarly, some researchers think of a human subject as a society of agents (Minsky 1987). We suggest that two separate societies (the human and the machine), when they interact towards the joint accomplishment of some task, constitute a society of agents. Agents (or processes) can be considered independently from their implementation (i.e. their location in a human or a machine): a process that is performed by a subject at the beginning of a session can be performed later on by his partner. Studies of collaborative problem solving have shown that peers spontaneously distribute roles and that this role distribution changes frequently (Miyake 1986). We use the term 'device' to refer indifferently to the person or the system that performs some process.

Within this metaphor, we can reconsider the relationship between social speech and inner speech: if an individual and a group are both modelled as a society of agents, inner speech and social speech are two instances of communication among agents. Inner speech is communication among agents implemented on the same device (intra-device communication), social speech occurs between agents belonging to different devices (inter-device communication). These levels of speech are two instances of the class 'communication among agents'. There is however a difference: communication between agents from different devices is external, it is observable. Patterns of inter-device communication can hence be induced and applied to intra-device communication.

These ideas have been implemented for designing Jerry Mander, the computerized co-learner in PEOPLE POWER. Jerry talks with the human learner (or another artificial learner) about the relation between the features of an electoral system and the results of elections. During this dialogue, Jerry stores relations between arguments. A network of arguments constitutes what we called a 'communication pattern'. Let us assume Jerry claims that Ward-5 should be moved from 'Southshire' to 'Northshire', because this would increase the score of his party in 'Northshire'. His partner may raise the objection that the party would lose votes in 'Southshire'. Jerry will then create a 'refutation' link between the first argument and its counter-argument. Similarly, dialogue patterns include 'continue-links' between arguments that have been verbalized consecutively in a successful argumentation. Jerry Mander reuses these dialogue patterns when it reasons alone. For instance, when it considers another move, Jerry Mander retrieves the counter-argument connected by a refutation-link and checks whether this counter-argument is valid in the new context. If it is, it refutes itself. Using a refutation-link between arguments (stored as rules) corresponds to a mechanism of specialization (adding a condition), while the use of continue-links corresponds to a form of chunking.

To implement the isomorphism between inner speech and social speech, we used the following trick: Jerry Mander uses the same procedure for talking with his partner and talking with itself. It uses a single procedure 'dialogue' which accepts two entries, a 'proposer' and a 'refuter'. The procedure call 'dialogue learner-X learner-Y' gives a real dialogue while the call 'dialogue learner-X learner-X' corresponds to individual reasoning (monologue). The implementation is actually a bit more complex. Each link is associated with a description of the context in which the connected arguments have been verbalized and has a numeric weight. This numeric weight evolves according to the partner's agreement ('social sensitivity') and to the electoral results ('environmental sensitivity'). A complete description of the learning mechanisms and their performance can be found in Dillenbourg and Self (1992).

3 Private Speech

Between inner speech and social speech, psychologists discriminate an intermediate level termed 'egocentric speech' by Piaget and 'private speech' by Vygotsky. These concepts are not completely synonymous (Zivin 1979). The most familiar examples of private or egocentric speech are the conversations conducted aloud by children who play alone. We might also refer to the verbal productions of people using computers on their own. Egocentric or private speech still has a rather social form (it is verbalized, it has some syntax, ...), but it has lost its social function (it is produced in the absence of any other person). For Piaget, it corresponds to some kind of uncontrolled production, while for Vygotsky, it has a self-regulating function (Zivin 1979). The interest in this intermediate level is that psychologists may extrapolate differences between social and private speech to speculate on the features of inner speech.

There is an interesting similarity between private speech and the idea of reification, a technique used in ILEs to support reflection (becoming aware of one's own knowledge and reasoning). Systems that attempt to promote reflection often present some trace of the learner's activities and of the environment's responses. Systems such as ALGEBRALAND (Collins and Brown 1988) or the GEOMETRY TUTOR (Anderson et al. 1985) facilitate the learner's reflection by displaying the learner's solution path as a tree structure. This representation shows that solving an equation or proving a theorem are not straightforward processes, but require numerous attempts and frequent backtracking. Such a representation reifies, makes concrete, some abstract features of the learner's cognition. It is not neutral, but results from an interpretation by the machine of the learner's action.

This graphical representation of behaviour has the ambiguous status of private speech. In systems such as ALGEBRALAND, TAPS (Derry 1990) or HERON (Reusser et al. 1990), this graphical representation serves both as a way of communicating with the system and as a tool for self-regulation. One can argue whether Vygotsky's theories on (verbal) speech are compatible with graphical languages used in modern interfaces. For Salomon (1988), "*all tools that we consider as prototypical and as intuitively appealing candidates for internalization have also a distinctive spatial form*".

4 Language Shift

Wertsch (1985) reports an interesting study which investigates the role of languages in internalization. This study zooms in the inter-psychological plane, observing mothers helping their children (2 1/2 and 3 1/2 year old) to construct a puzzle in accordance with a model (the same puzzle already built). Wertsch contrasted the language used by mothers to refer to puzzle pieces according to the child's age: mothers of younger children designate directly the piece by pointing to it or by its colour (e.g. "a green piece"), while mothers of older children refer to pieces with respect to the problem-solving strategy (e.g. "one colour that's not the same"). For Wertsch, the cognitive processes required to participate in a dialogue based on a 'strategy-based referential perspective' are virtually equivalent to the cognitive processes necessary to apply this strategy without the mother. This study weakens the dichotomous distinction between the social and internal planes, since changes inside the social plane may be more important than the social-internal transition.

We translated this shift in language into a design principle for ILEs (Dillenbourg 1992). Let us decompose the difference between a novice and an expert into several levels of skills. When learners solve problems at level X, they interact with the system through some command language CLx. The system, as the mothers in Wertsch's observations, has a second language available, called the description language (DL). The description language reifies the implicit problem solving strategy by displaying a trace of the learner's activities. The system uses this description language in feed-back in order to associate the two descriptions of the same solution, one expressed in the command language and the second in the description language. The language shift occurs when the system moves up in the hierarchy of expertise levels. After a move to the next level (X+1), learners receive a new command language which includes the concepts that were introduced by the description language at level X. This language shift can be expressed by the equation $CL_{x+1} = DL_x$. After the language shift, learners are compelled to use explicitly the operators or strategies that where previously implicit (but reified in the description language).

This principle has been applied to the definition of the successive microworlds in MEMOLAB (Dillenbourg and Mendelsohn 1992). MEMOLAB includes three successive microworlds or levels, with increasingly powerful command languages (and increasingly complex problems to solve). At level 1, a psychological experiment is built by assembling chronological sequences of concrete events. At level 2, the learner does not describe each concrete event but builds the treatments to be applied to each group of subjects. At level 3, the learner directly defines the experimental plan, i.e. the logical structure of the experiment. At levels 1 and 2, when an experiment design has been completed, the experiment is 'redisplayed' with the formalism used at the next level.

5 Social Grounding

In People Power, the internalization mechanism has been implemented as the simple storage of dialogue patterns. It is clear however that internalization is not a simple recording process, but a transformation process. There exist interesting similarities between the transformations occurring during internalization and those occurring during social grounding. Social grounding is the mechanism by which two participants in a discussion try to elaborate the mutual belief that their partner has understood what they meant to a criterion sufficient for the current purpose (Clark and Brennan 1991).

For Vygotsky, inner speech has a functional similarity with social speech but loses its structural similarity. The difference between social and inner speech is due to the fact that "inner speech is just the ultimate point in the continuum of communicative conditions judged by the degree of 'intimacy' between the addresser and addressee" (Kozulin 1990, p. 178). The main transformation observed as a result of the intimacy between the addresser and addressee is a process of *abbreviation* (Kozulin 1990; Wertsch 1979). Interestingly, Krauss and Fussell (1991) found the same abbreviation phenomena in social grounding. They show that the decrease in expression length is a function of the feed-back given by the listener. Internalization and social grounding are two phenomena during which the addresser acquires information about the addressee's understanding of his messages.

The work on grounding is very important for designers of ILEs. For Roschelle (1990), the main quality of the representations displayed on the screen is not their epistemic fidelity (Wenger 1987), but the extent to which those representations enable two learners to test under increasingly tighter constraints the degree to which their interpretation of physical phenomena were shared. Collaboration should be concerned with what is on the screen, since it is the main reference to establish shared meanings. In MEMOLAB, we have chosen a solution based on this principle. Let us imagine two production systems that use a common set of facts. They share the same representation of the problem. Any fact produced by one of them is added to this common set of facts. Hence, at the next cycle of the inference engine, this new fact may trigger a rule in either of the two rule-bases. Now, let us replace one computerized expert by a human learner. The principle may still apply provided we use an external problem representation instead of the internal one. The common set of facts is the problem representation as displayed on the interface. All the conditions of the machine's rules refer only to objects displayed on the screen. The actions performed by the rules modify the problem representation. In short, the shared representation is visible by both partners and can be modified by both partners. We do not claim that they share the same 'internal' representation, but simply that a shared concrete representation facilitates social grounding. Some recent experiments with MEMOLAB (Dillenbourg et al. 1993) revealed mechanisms of human-machine grounding: the learner perceives how the machine understands him and reacts in order to correct eventual misdiagnosis.

6 Conclusions

Along the last years, the concept of collaboration has evolved from the notion of socio-cognitive conflict (Doise and Mugny 1984) to the process of constructing shared meanings (Roschelle 1990). PEOPLE POWER and MEMOLAB are still based on the notion of disagreement, i.e. a bipolarisation of the continuum which goes from a total absence of understanding to fully shared understanding. The challenge of ILE designers is to build mechanisms of human-computer social grounding. Human-computer interactive systems are interesting devices to study internalization because there is no fundamental difference between talking to a computerized system (pseudo-social speech) and talking to oneself with computerized representations (reflecting).

References

Anderson, J.R., Boyle, C.F., Yost, G. (1985) The Geometry Tutor. Proceedings of the Ninth International Joint Conference on Artificial Intelligence (Vol. I, 1-7). Los Angeles. August 18-23.

Clark, H.H., Brennan S.E. (1991) Grounding in Communication. In L. Resnick, J. Levine and S. Teasley. Perspectives on Socially Shared Cognition, 127-149. Hyattsville, MD: American Psychological Association.

Collins, A., Brown, J.S. (1988) The Computer as a Tool for Learning through Reflection. In H. Mandl, A. Lesgold (Eds), Learning Issues for Intelligent Tutoring Systems, 1-18. New York: Springer.

Derry, S.J. (1990) Flexible Cognitive Tools for Problem Solving Instruction. Paper presented at the AERA symposium, Computers as Cognitive Tools, April. Boston, MA.

Dillenbourg, P. (1992) The Language Shift: a mechanism for triggering metacognitive activities. In M.Jones and P.H. Winne (Eds). Adaptive Learning Environments: foundations and frontiers, 287-316. NATO ASI Series F, Vol. 85. Berlin: Springer.

Dillenbourg, P., Self, J.A. (1992) A computational approach to socially distributed cognition. European Journal of Psychology of Education, 3, (4), 353-372.

Dillenbourg, P., Mendelsohn, P. (1992). The genetic structure of the interaction space. In E. Costa (ed), New Directions for Intelligent Tutoring Systems, 15-27. NATO ASI Series F, Vol. 91. Berlin: Springer.

Dillenbourg, P., Hilario, M., Mendelsohn, P., Schneider D., Borcic, B. (1993) The Memolab Project. Research Report. TECFA Document. TECFA, University of Geneva.

Doise, W., Mugny, G. (1984) The social development of the intellect. Oxford: Pergamon Press.

Kozulin, A. (1990) Vygotsky's psychology. A biography of ideas. Harvester, Hertfordshire.

Krauss, R.M., Fussell, S.R. (1991) Constructing shared communicative environments. In L. Resnick, J. Levine and S. Teasley (eds). Perspectives on Socially Shared Cognition, 172-202. Hyattsville, MD: American Psychological Association.

Minsky, M. (1987) The society of mind. London: William Heinemann.

Miyake, N. (1986) Constructive Interaction and the Iterative Process of Understanding. Cognitive Science, 10, 151-177.

Piaget, J. (1928) The language and thought of the child. New York: Harcourt.

Reusser, K., Kampfer, A., Sprenger, M., Staub, F., Stebler, R., Stussi, R. (1990) Tutoring mathematical word problems using solution trees. Research Report No 8, Abteilung Pädagogische Psychologie, Universität Bern, Switzerland.

Roschelle, J. (1990) Designing for Conversations. Paper presented at the AAAI Symposium on Knowledge-Based Environments for Learning and Teaching, March. Stanford, CA.

Salomon, G. (1988) AI in reverse: computer tools that turn cognitive. Journal of educational computing research, 4, 12-140.

Salomon, G. (1990) Cognitive effects with and of computer technology. Communication research, vol. 17, (1), 26-44.

Vygotsky, L.S. (1978), Mind in Society. The Development of Higher Psychological Processes. Edited by M. Cole, V. John-Steiner, S. Scribner, E. Souberman Harvard University Press. Cambridge, MA: Harvard University Press.

Wenger, E (1987) Artificial Intelligence and Tutoring Systems: Computational and Cognitive Approaches to the Communication of Knowledge. Los Altos, CA: Morgan Kaufmann.

Wertsch, J. V. (1979) The regulation of human action and the given-new organization of private speech. In G. Zivin (Ed), The development of self-regulation through private speech, 79-98. New York: John Wiley & Sons.

Wertsch, J.V. (1985) Adult-Child Interaction as a Source of Self-Regulation in Children. In S.R. Yussen (ed). The growth of reflection in Children, 69-97. Madison, Wisconsin: Academic Press.

Zivin, G. (1979) Removing common confusions about egocentric speech, private speech and self-regulation. In G. Zivin (ed) The development of self-regulation through private speech, 13-50. New York: John Wiley & Sons.