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Distributed Cognition and Educational Practice

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The objective of this article is to present a brief historical overview of ideas related to the distribution of cognition, offer a critical appraisal, and outline some of the implications for the teaching and learning practice. First, the article provides a description of the mind as disembodied and disembedded, an image that has come to dominate western psychological thought. Second, the article focuses on a set of ideas that challenge this notion of the mind as the locus of all cognition and intelligence: distributed cognition. The main tenets of distributed cognition in two psychological traditions, cognitive science and educational psychology, are presented. Third, the article considers another influential tradition that has significantly influenced the development of conceptions of distributed cognition: cultural-historical psychology. Fourth, distributed cognition ideas in cognitive science and educational psychology are critically appraised, so that similarities and differences are highlighted. The article concludes with a discussion of some of the implications of distributed cognition ideas for the teaching and learning practice.

Socrates: *What do you say of him, Meno? Were not all these answers given out of his own head?*

Meno: *Yes, they were all his own*.

Plato*, Meno*

In one of the first recorded texts ever to address questions about the mind and the nature of knowledge, the Platonic dialogue Meno, Socrates invites Meno to observe his interaction with a young slave to decide on whether the slave is learning something from Socrates or is simply remembering known facts. Socrates makes a clear distinction between teaching and telling, considering, asking questions as distinct from teaching ("I am not teaching the boy anything, but only asking him questions"). In the course of the interaction, Socrates elicits certain knowledge of geometry from the slave. Meno is compelled to agree on that all the answers the slave gave were "given out of his own head" and further accepts this "spontaneous recovery of knowledge" on the part of the slave as "recollection." Even though Socrates merely aimed to show that recollection is a main source of knowledge, the dialogue is interesting in two main respects. First, it portrays a certain image of knowledge that is basically seen as being prior to existence. Second, it delineates roles for the teacher and the learner, thereby providing a model of cognition that can be utilized for instruction: teaching is presented as a process of eliciting knowledge from rather than presenting knowledge to the leaner.

The present article focuses on the notion of cognition as distributed, a notion which is largely incompatible with Socrates'; interpretation that the answers the slave gave were "given out of his own head", an interpretation that eventually has come to dominate western philosophical and psychological thought. By presenting and discussing views that support the notion of cognition as distributed, we will cast doubt on Socrates' account that the slave was unassisted in arriving at the respective understanding of a geometrical fact.

DISTRIBUTED COGNITION: A BRIEF HISTORICAL OVERVIEW

Descartes carried forward this Platonic image of knowledge, thereby separating the mind from the body and treating the mind as a self-standing, independently operating entity (Haugeland, 1998). While for the first few decades of psychology as a scientific discipline the mind was a legitimate object of study through introspection (cf. Cole's, 1996, account of the second psychology), ushering in the behaviorist rein shifted the focus from the mind to objective behavior. Finally, the cognitive revolution of the '50s restored the emphasis on the mind (Gardner, 1987). This evolution helps understand why the mind has been treated as disembodied and disembedded,

cognition being "in the head" as a property of the individual mind. Most of the current psychological research is either explicitly or implicitly based on this conception of cognition: cognitive processes are thought of as residing inside the head, their study is largely decontextualized, and the individual is used as the unit of analysis. For instance, the study of memory typically involves the examination of how individuals memorize a body of knowledge, how they encode it and integrate it into the existing knowledge structures, and how they retrieve it from those structures. The study of memory usually involves abstract tasks that are typically meaningless and likely to have very little connection with the real world. Finally, experiments are carried out in a "white room" where subjects are neither allowed to use any artifacts for remembering (e.g., take notes as they would usually do in real life if they had to remember long meaningless strings of symbols) nor turn to others present in the environment (family members, partners, colleagues, friends) and use them as memory aids (e.g. asking a colleague in the office to remind them to do something as they would normally do in real life). This approach to the study of psychological processes is indicative of the tendency to think of the individual mind as the locus of all cognition and intelligence.

In recent years, however, the mind-body dualism has been challenged both on philosophical (e.g., Winograd & Flores, 1987; Dreyfus & Dreyfus, 1990) and empirical grounds (Lave, 1988; Lave & Wenger, 1991; Hutchins, 1995a; Clark, 1997). Owing to such theoretical and empirical advances, new models of the mind and cognition have surfaced aiming to transcend the limitations of the dualistic model: situated cognition and distributed cognition. Our specific focus in this article will be on the latter.

The idea that cognition is distributed is not new as Cole and Engestrom (1993) pointed out. The revived interest in the idea of cognition as distributed has been attributed to; (a) the fact that people rely on computer artifacts to handle a wide variety of cognitive tasks, (b) the influence of cultural-historical psychology, and (c) the dissatisfaction with the notion of cognition as a property of the individual mind (Salomon, 1993a). In spite of this renewed interest, it should be stressed that distributed cognition is neither a coherent theory nor a theoretical framework. Rather, it can be roughly described as a set of ideas about the nature of cognition and how it relates to fellow people and artifacts. We will present an integrated account of distributed views of cognition in two different traditions: *cognitive science* (Hutchins, 1995a; Clark, 1997), and *educational psychology* (Salomon, 1993; Resnick, Levine, & Teasley, 1991). We will mainly focus on the volume by Salomon even though we refer to both volumes as falling under the category of educational psychology. It should be noted, however, that as opposed to

the volume by Salomon, which is mainly addressing psychologists and educators, the volume by Resnick, Levine and Teasley is much broader in scope covering areas such as psychology, education, conversation, language and communication (Schegloff, 1991; Heath, 1991; Rogoff, 1991; Hutchins, 1991; Resnick, 1991; Lave, 1991).

Distributed Cognition in Cognitive Science

While in traditional cognitive science cognition was considered to reside in the head, recent approaches have moved the boundaries of cognition beyond the head (Norman, 1993; Hutchins, 1995a; Clark, 1997; Haugeland, 1998). The limitations of cognition as symbol-based computation are being highlighted by cognitive scientists who acknowledge that, for certain purposes, it is more appropriate to consider cognition (and intelligence) as a property of the whole system within which the individual functions rather than as something limited by the skin or skull (Clark, 1997; Greeno & Moore, 1993; Zhang & Norman, 1994; Norman, 1993; Hutchins, 1995a; Hutchins & Klausen, 1998). The image of mind that emerges is that of the leaky mind "escaping its natural confines and mingling shamelessly with body and with the world" (Clark, 1997, p. 53).

The appropriateness of using the individual as a unit of analysis is questioned, as it is maintained that the properties of individual cognition cannot be understood by simply studying individual cognition per se: rather, one should look at the whole system within which the person operates using various tools (Hutchins, 1995a; 1995b; Hutchins & Palen, 1998). By way of illustration, Hutchins (1995b) reached two main conclusions in his study of the memory processes in a commercial airline cockpit. First, memory functions are more a matter of interpretation of material symbols by the pilots than a matter of recollection of these symbols from their memories. Second, the memory of the cockpit is not made of individual pilot memory alone; focusing on individual pilot memory is insufficient in understanding the phenomenon of memory, because a considerable portion of the mnemonic function takes place outside the individual pilot memory, namely outside of the individual pilot head.

Hutchins (1995a) has studied how cognition makes use both of the *natural environment* to offload some of the computational burden involved in calculations and *specially designed artifacts* which crystallize knowledge and practice thereby saving mental effort. Regarding the use of the *environment* as a tool, Hutchins (1995a) provided a colorful example with his description of Micronesian navigation, where navigators are sailing for several

days out of the sight of land without using any typical western mechanical, electrical or magnetic resources. While at first sight it appears that they are poorly equipped for such a task, they nevertheless navigate very accurately: they know the bearings of the point of departure, the destination, and can indicate other islands off to the side of the course even though these are out of sight. Even though these navigators are ostensibly not using any navigational instruments (e.g., compass), they actually draw on a number of sources of information available in the environment such as: (a) the presence of submerged reefs which change the apparent color of the water; (b) the interaction of swells with islands which produces distinctive swell patterns; (c) the winds and weather patterns in the sky; (d) seabirds, especially close to or around islands, and (d) stars, for navigating during the night. It is precisely this type of opportunism typically exhibited by humans in exploiting the environment as a tool that Clark (1997) referred to as the "007 principle".

Regarding *artifacts* and *environmental structuring*, Hutchins (1995a) argued that in traditional cognitive science one serious error is the attribution to individual minds of properties that are derived from the use of cultural artifacts. He noted that human environments are "artificial" and human cognitive abilities stem precisely from using these artificial environments. Haugeland (1998) demonstrated how intelligence is derived from the structuring of the environment and that it does not have much meaning outside of such an environment: "Let me tell you how I get to San Jose: I pick the right road (Interstate 88 south), stay on it, and get off at the end. Can we say that the road knows the way to San Jose, or perhaps that the road and I collaborate? ... I suggest that the road should be considered integral to my ability" (p. 234). As for the use of *artificial tools*, Hutchins (1995a) demonstrated how the creation of specific tools saves mental effort and crystallizes knowledge by referring to charts ("the cartographer has already done part of the computation for every navigator who uses his chart," p. 173) and nautical slide rules (the navigator eventually succeeds by doing less because the tool does more). In a sense, then, "our brains make the world smart so that we can be dumb in peace!" (Clark, 1997; p. 180).

Distributed Cognition in Educational Psychology

Researchers in educational psychology have traditionally concentrated on the individual as the bearer of cognition and intelligence. Recent trends, however, tend to describe cognition as extending beyond the skin as well. The notion of cognition as distributed acquired momentum in educational

psychology in the early 1990s with the publication of two major works: *Perspectives on Socially Shared Cognition* by Resnick, Levine and Teasley in 1991, and, more importantly, *Distributed Cognitions* by Salomon in 1993. Of particular interest here is the latter and especially Pea's (1993) distinction between two dimensions of distribution of cognition: a *social* dimension and a *material* one. Assuming that an individual is performing a task, the material dimension of the distribution refers to the incorporation of all kinds of mental and physical artifacts in which cognition is encapsulated, while the social dimension of the distribution refers to the involvement of social others who assist by functioning as cognitive resources. While this distinction is artificial it nevertheless is a very useful one. A similar distinction is also made by Cole and Engestrom (1993) in their more encompassing model that involves, among other parameters, the distribution of cognition over people and artifacts.

Regarding the *social distribution* of cognition, Cole and Engestrom (1993) emphasized that in the mastery of a cognitive task such as learning to read the cognitive processes involved are not solely an individual matter as they are distributed among teacher, student, and other cultural artifacts employed in the activity. Overall, the organization and the structuring of the social and material environment in the context of learning to read serves the purpose of regulating the reading act for the child before the child can autonomously regulate it himself or herself. In this sense, learning to read on the part of the child entails performing more reading operations with the passing of time (Cole, 1996). The social dimension of the distribution of cognition, even in the case of a sole individual solving a problem, is also evident in Pea's (1993) argument that each phase of Polya's six stage problem-solving model is not a construction of the individual mind but also the outcome of cooperation with and guidance from others, and as a consequence the borders between the stages become vague when one pursues an analysis of the problem solving process. The social distribution of cognition has also been aptly illustrated with the cases of children drawing on teachers, fellow students, and academic materials for shaping and directing their activities (Moll, Tapia, & Whitmore, 1993) as well as with the cases of children interacting with more experienced peers, getting advice and assistance from them, and eventually accomplishing more than what they could individually accomplish (Hatch & Gardner, 1993).

With respect to the *material distribution* of cognition, whenever a tool is used in the execution of a task, it participates in the outcome as well, as it contributes to it in a very unique way: it guides, augments, and structures the activity, saves mental work, and helps avoid errors (Pea, 1993). Devices such as jogger pulse meters, automatic street locators, currency exchange

calculators, world time clocks, and weight-loss calculators "reify common problem formats and automate solution-finding procedures" (p. 53). Because we take them for granted, we do not notice them and, as Pea noted, once they become invisible, intelligence is typically attributed only to the individual using them. This interpretation, according to Pea (1993), is inaccurate since the tools literally carry intelligence in them as they bear the patterns of previous reasoning, and they constitute a realization of distributed intelligence. Perkins (1993) argued that human artifacts constitute an integral part of human intelligence because (a) the surround participates in cognition as a vehicle of thought, and (b) learning does not reside only in the mind of the learner but also in the arrangement of the surround. In this sense the material dimension of the distribution of cognition involves the use of either the physical environment itself or cultural artifacts in the performance of a certain task.

With regard to the use of the *environment* as a cognitive tool, people frequently use either physical tools existing in the environment or aspects of the environment itself for augmenting their capabilities and for alleviating cognitive burden. For instance Lave, Murtaugh, and de la Rocha (1984) reported the case of a shopper who "found an unusually high priced package of cheese in a bin. He suspected an error. To solve the problem, he searched through the bin for a package weighing the same amount and inferred from the discrepancy between the prices that one was in error" (p. 77). This type of problem-solving behavior shows that, instead of engaging in mental arithmetic—which would make the solution more effortful and error-prone—the shopper resorted to the environment in an attempt to avoid mental effort and make the problem solution much easier, essentially offloading the computation onto the environment itself and using it as a tool.

Regarding the use of *artifacts*, humans are not only confined to using the environment for avoiding mental effort. Our intelligent activity as a species is largely manifested in the creation and use of tools, both physical and cognitive ones. Physical tools (such as hammer) increase human strength, while cognitive ones (such as language, print, mathematics) enhance human cognition and its problem solving capabilities. The list of such cognitive tools in our surroundings is probably a very long one. For example, Pea (1993) argued that with the help of imaging software computers can help the visualization procedure and consequently contribute to the understanding of complex relationships in a way that would have been impossible without them. Therefore, in cognitive tasks that involve advanced computing programs, the overall outcome is a result of the combination of the contributions of the scientist, of the designers who developed the system, and of the particular visualization technology.

THE INFLUENCE OF CULTURAL-HISTORICAL PSYCHOLOGY

As already alluded to, one of the reasons for the contemporary surge of interest in the distribution of cognition in educational psychology was the publication of the works of Vygotsky in the West, which in turn makes a presentation here all the more compelling. As opposed to other psychological theories, Vygotsky's emphasis on the social influences on the development of the psychological self was paramount, as it is manifested in his general *genetic law of cultural development*. On the other hand, he also attributed primary importance to the *mediation* of human psychological activity by symbols.

Regarding the former, the role of others (parents, teachers, and peers) in the context of ontogenetic development is deemed to be crucial. This is clearly reflected in Vygotsky's *general genetic law of cultural development*: "every function in the child's cultural 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; p. 57, emphasis in the original). Wertsch (1991) provided an illustration of this law by considering the case of a young child who was assisted by his mother to remember where his toy was. He points out that it is impossible to say that either participant did the remembering, as neither the child could have effectively managed his memory resources nor the mother could have known the position of the toy. The cognitive act of remembering was carried out on the inter mental plane.

With respect to *mediation*, humans typically use tools in their attempts to accomplish a certain goal and thus, interact with nature indirectly, through tool-use. Marx and Engels' argued that human activity is mediated by material/labor tools, Vygotsky proposed that it is also mediated by psychological tools: "the sign acts as an instrument of psychological activity in a manner analogous to the role of a tool in labor" (Vygotsky, 1978, p. 52). These "psychological tools" or "instruments" include: "language; various systems for counting; mnemonic techniques; algebraic symbol systems; works of art; writing; schemes, diagrams, maps, and mechanical drawings; all sorts of conventional signs" (Vygotsky, 1960/1981a, p. 137). The incorporation of signs in cognitive activity entails it's transformation along two main dimensions (Vygotsky & Luria, 1994). First, a natural psychological process is transformed into a cultural one, changing its structure and process. For example, in the case of memory, Luria (1928/1994) pointed out that natural memory is based on the recollection of facts while mediated (i.e., cultural) memory is based on recognition of signs (e.g., print) instead of their recollection. Second, a natural psychological process becomes "extra-cortical" when

a psychological tool is used and thus, it moves beyond its natural confines. In the memory example previously referred to, the operation goes well beyond the limits of what is natural in remembering, that is the use of brain cells. When a sign/psychological tool is used as a means for remembering, memory becomes "inter-cortical," in the sense that an external tool—a means which does not constitute a part of the biological makeup of the organism—is used in remembering. Therefore, the task of memory is accomplished by means of employing both natural resources (cortical) and external signs (extra-cortical) (Vygotsky & Luria, 1994).

Some Thoughts on Similarities and Differences

Having presented ideas related to the distribution of cognition in at least two disciplines and examined the influences of cultural-historical psychology; we will now comparatively examine them, highlighting similarities and differences. Five main points will be made.

First, Nardi (1996) put both contemporary distributed cognition approaches (the ones in cognitive science and educational psychology) under the same category that is, distributed cognition. We believe that this categorization is not warranted because, despite surface similarities, educational psychology scholars place strong emphasis on the social dimension of this distribution, being heavily influenced by Vygotsky's views on the social origins of individual mental functioning. Thus, even though proponents in both traditions emphasize the fact that cognition is distributed, the scholars in the educational psychology do not perceive of the distribution as only having a material dimension, that is distributed over tools upon which Hutchins mainly focused, but also as having an essentially social dimension, that is distributed over people (primarily reflected in the contributions by Pea and by Cole & Engestrom). In this respect it is interesting to note that not only did Vygotsky consider individual mental functioning to have social origins but he also went as far as to say that "even when we turn to mental processes, their nature remains quasi-social. In their own private sphere, human beings retain the functions of social interaction" (Vygotsky, 1960/1981b, p. 164).

Second, Cobb (1998) treated Pea's and Hutchins's accounts as theories while, to be sure, these do not constitute "theories" as described earlier. Furthermore, Cobb (1998) argued that, from the perspective of a mathematics educator, Pea and Hutchins "subscribed to similar characterizations of the individual" (p. 193), as the individual is treated in both accounts in a similar way

and argued that the differences between their respective accounts are ones of terminology. As was pointed out already, this interpretation is not warranted, because the origins and objectives of the two accounts are different. Nevertheless, in discussing Pea's and Hutchins's accounts, Cobb makes an interesting observation regarding the nature of the individual who is depicted as "the disembodied creator of internal representations who inhabits the discourse of mainstream psychology" (p 195). He concluded that the choice offered is "either accepting one specific characterization of the individual—that of mainstream psychology—or rejecting the very notion of the individual as a legitimate unit of analysis" (p. 195). Additionally, he argued, "If we accept Hutchins's arguments, we take an approach that seems to involve partitioning rather than distributing intelligence. If we follow Latour's line of reasoning, we push cognition out beyond the skin, thereby distributing intelligence by 'emptying the person'" (p. 196). We believe that casting the debate in terms of polar extremes is neither productive nor warranted.

Cobb's alternative proposal, genetic epistemology, might be theoretically appealing due to its ecological nature but it still comes with its own conceptual baggage. After all, he still talks about analyzing individual students' conceptions and activity. It is debatable whether such an approach actually overcomes the dualisms it set out to counter and the limitations of distributed cognition approaches. Finally, it should be pointed out that Pea's and Hutchins's accounts of cognition as distributed, much like the situated cognition perspective, emerged as a response to the prevalent image of the mind, something not quite taken into account by Cobb. As far as we understand them, the distributed cognition approaches do not claim to constitute solutions much less to provide ones; they just provide alternative conceptions and should be credited for doing just that.

Third, Nardi (1996) pointed out that in Hutchins's account of the distribution of cognition humans and tools are fundamentally the same, that is they have a symmetrical role, and the same language can be used to describe both of them. We basically agree with this line of reasoning. On the other hand, our interpretation of Hutchins's work is that, despite the fact that he has made ingenious observations, he nevertheless seeks to answer old questions: "one can still ask the same questions of a larger, socio-technical system that one would ask of an individual" (Hutchins, 1995b, p. 226). We think that his approach falls short in that he is concerned with how information is represented, not within the individual head but within the cognitive system, and how information is propagated in the system. It should be emphasized that even though it is perfectly legitimate to study how information is represented and propagated in the system, in essence the approach is "explicitly cognitive...such a theory can provide a bridge between the information

processing properties of individuals and the information processing properties of a larger system" (Hutchins, 1995b, p. 286-87). Hutchins's various ethnographic accounts involving the creation and use of artifacts are fascinating, but his work focuses exclusively on artifacts, on their history and development, on their use for computational purposes (i.e. problem solving). Moreover, he does not consider that both the creation of artifacts and their mastery are fundamentally social processes; neither does Hutchins make these social processes his object of study.

Fourth, in Cultural-Historical psychology, the social with the material are explicitly linked. Vygotsky viewed mediation as a higher mental (i.e., cultural) process, and by definition considered all higher mental processes to be inherently social, having a profound cultural nature. Young children do not invent or create signs (or symbols)—they receive them from adults. Signs mediate psychological processes and elevate them to a higher level, allowing a person to achieve much more than would be biologically possible. Thus, not only did Vygotsky emphasize the social origins of individual mental functioning and the mediated character of human thought but he also linked the two, considering them to be intertwined.

Finally, this comparative examination would not be complete without reference to recent approaches which have many parallels with the ideas related to the distribution of cognition such as Sociocultural Psychology or Cultural-Historical Activity Theory (CHAT). A presentation of these two frameworks is definitely beyond the scope of this introductory article. Despite important differences between the two frameworks (see Cole, 1996 for more details), it is interesting to note the shared perspectives in terms of unit of analysis. More specifically, both frameworks propose mediated action as the unit of analysis by drawing either on the works of Vygotsky and Leont'ev (CHAT - e.g., Cole & Engestrom, 1993; Cole, 1996), or Vygotsky, Bakhtin, and Burke (Wertsch, 1991; 1998). For instance, Wertsch (1998) suggested giving analytic primacy to mediated action because by focusing on the agent-tool relationship one necessarily has to move beyond the traditional exclusive focus on the individual. Once one focuses on the user-tool dyad many other important factors surface such as the purpose and context of the activity performed. This, in turn, entails that the cultural, historical, and institutional contexts within which this act occurs are linked (Wertsch, 1998). What is particularly interesting about sociocultural psychology is the integration of Bakhtin's ideas—such as genre and dialogicality—with the ones of Vygotsky on mediation and the social origins of individual mental functioning. Wertsch (1998) demonstrated how the appropriation of the relevant genre in the case of reciprocal teaching results in enhanced reading performance by the student who mastered the specific genre.

Implications for Educational Practice

Much of current educational practice is founded on the assumption that cognition resides in the individual head. The conception of the individual as the sole bearer of all cognition is widespread and is manifested in the conceptions of teaching and learning methods as well as in the classroom and examination practices. For instance, as far as the teaching practices are concerned, lecturing (expository instruction) is a standard method of teaching by means of which students are introduced to the new material. The underlying learning assumption is that the learner is a passive recipient of information and that teaching is the process through which the teacher instills information in the heads of the learners, who will in turn commit this information to memory where it will hopefully be maintained for future retrieval. Even ostensibly more interactive forms of teaching such as Socratic dialogue and questioning (getting student input and providing feedback—IRF sequences) are also indicative of the penchant to view cognition as a property of the person as, even in the case of questioning, the bulk of the information and the major cognitive structure is still provided by the teacher with the students filling in the open slots. Regarding classroom practices, it must be noted that while in the real world students will be expected to exhibit mastery of certain skills in conjunction with others and artifacts, the educational system mainly prepares them for solo work. For instance as a rule assignments hardly ever require group work. In addition, during exams students have to solve problems or perform certain designated tasks but are not allowed to cooperate with fellow classmates, much less resort to artifacts such as calculators, computers, or even textbooks. These practices are indicative of the notion of cognition as residing in the individual head, as being a property of the individual who accomplishes everything autonomously, unassisted by others or artifacts.

In the remainder of this section we will briefly address the following question: *given the material and social dimension of the distribution of cognition, what are the main implications for the teaching and learning practice?*

Regarding the *material dimension* of the distribution of cognition, it should be born in mind that when one or more tools are incorporated in the performance of a task, fundamental changes as to the cognitive processes involved are effected. Depending on the nature of the task and the tool used, some of the mental processing (and physical labor) involved in carrying out the task is necessarily taken over by the tool. As a consequence, there is less room and opportunity for the learners to engage in mental processing (and, consequently physical labor). The task is fundamentally

transformed, essentially being restructured with the use of the tool. Thus, the possibilities for mindful engagement on the part of the students at the same levels are drastically reduced. In fact, learners have to be engaged less because the tool accomplishes more.

By means of an illustration, we examined the changes that are effected when correlation problems are solved with a computer spreadsheet as opposed to the more conventional paper and pencil approach (Karasavvidis, 1999). Students in the paper and pencil condition were tutored by their geography teacher in how to solve correlation problems using paper and pencil while students in the computer spreadsheet condition were tutored in how to solve correlation problems with the aid of a computer spreadsheet. Results showed that tool affordance allowed for different cognitive operations: students using the computer spreadsheet were more engaged in the interpretation of graphs and the formulation of hypotheses, as there was little opportunity to be involved in anything else. On the other hand, students using paper and pencil were more involved in the laborious point-to-point graph construction as making graphs was a prerequisite to solving the problems. Therefore, the incorporation of a computer tool in the solution process meant that, by default, some of the cognitive processing is carried out by the tool so that there is less opportunity for the learners to carry out part of that processing (see Karasavvidis, 1999, for more details). Also, the results showed that the tool used defines what the task is, and how it will be perceived and understood. Consequently, what the students in the two conditions experienced, learned, mastered, and understood was of a different nature. Students in the paper and pencil condition had to make a graph and spent most of their time making it: they acquired a deeper understanding of the construction process, and learned several shortcuts and tricks to reduce the labor involved without compromising the accuracy of the graphs. On the other hand, students in the computer spreadsheet condition were more involved in the interpretation of graphs, as graphs were produced instantly with a few mouse clicks; hence they acquired hardly any algorithmic knowledge regarding graph construction. The bottom line is that the introduction of the computer spreadsheet into the solution process profoundly transformed what it meant to solve correlation problems to such an extent that most of the initial learning goals could no longer be pursued: apart from interpreting graphs, hardly any other cognitive skill could be targeted in both conditions.

On the basis of these findings it easily follows that the whole teaching and learning culture will have to be readjusted. The teaching and learning conceptions should also be reformulated as to what learning is and how it is

affected. Additionally, the curriculum would have to be considerably revised in many respects. For example, new tasks would have to be developed which are not of an entirely algorithmic nature; some tasks would have to be restructured and redesigned; other tasks might have to be discarded altogether as the cognitive skills required for their completion are rendered unnecessary. More practical and situated tasks should be sought which do not require unique solutions or which do not even have solutions at all. Moreover, the evaluation practices would also have to be reconsidered to conform to this new conception of cognition, learning, and teaching: certain cognitive tools would have to be present if some tasks are to be solved by learners and learners should be allowed to cooperate with other learners to achieve certain goals. Overall, new learning objectives would have to be set. The bottom line is that we cannot expect to introduce an innovation into the classrooms (such as the computers, LANs, and the Internet) and target the same learning objectives. Because cognition is embedded in computers and certain cognitive processes are transformed into mechanical ones (e.g., mouse clicks), it is obvious how cognition is distributed in this sense. Thus, cognition is encapsulated in all sorts of cultural tools we use and as a consequence if the performance of a task involves the use of such a cultural tool the outcome is jointly produced by the intelligence of the user/learner coupled with the intelligence built into the tool.

Regarding the *social dimension* of the distribution of cognition, traditional conceptions of teaching tend to overemphasize the presentation of information, much of the emphasis being placed on the structuring of new information so that it can be better maintained in memory. Even though the presentation of new information deserves more attention, we should not be exclusively concerned with it. We should also focus on the ways which foster the progressive participation of students into tasks, that is use constructs such as scaffolding, coaching, and apprenticeship, thereby moving beyond the concept of feeding learners with new information as if that is all what is instructionally required. We should focus on the learning process itself so that the conception of the learner as an empty box to be filled with knowledge is eventually overcome.

Vygotsky (1987) described how cognition is distributed in a social sense and how the performance of an individual skill (and hence its mastery) is not an individual matter alone: “when the school child solves a problem at home on the basis of a model that he has been shown in class, he continues to act in collaboration, though at the moment the teacher is not standing near him. From a psychological perspective, the solution of the second problem is similar to this solution of a problem at home. It is a solution accomplished with the teacher’s help. This help—this aspect of collaboration—is

invisibly present. It is contained in what looks from the outside like the child's independent solution of the problem" (p. 216, emphasis added). In this particular case Vygotsky referred to an exemplary solution but the same holds for genres and algorithms alike.

What is important to bear in mind is that mastering such cultural tools is not an individual matter. The process of learning is inherently social in nature and, therefore, their mastery is distributed. Since cultural tools are not invented by young society members (after all the process of acculturation is about introducing young members to the tools and the practices of their society) the process of getting to know and master them requires adult supervision and is in fact accomplished through adult assistance. Initially, adults are charged with monitoring everything, demonstrating a lot, and regulating young members as long as they cannot accomplish that individually. With the passing of time and as experience increases with practice, students can perform some sub tasks autonomously without any need to check with the adults. In any event, acculturation is a process which is mediated by social others who are charged with the gradual introduction of the young members into a system of practice, its tools, and logic. Thus, young society members do not only receive the contemporary cultural tools ready-made; they also receive instruction in how to use them and their mastery is a long lasting process which de facto involves social others.

We have only presented a small scale micro genetic example of how the incorporation of a computer tool restructured and essentially transformed the cognitive practice of solving correlation problems. Saljo (1999) pointed out that the implications of how cognitive tools impact learning have not as yet been worked out. Future research should address this issue and determine the implications on the levels of both theory and practice.

CONCLUSIONS

We will conclude this article by revisiting the Platonic dialogue referred to at the outset. Because Socrates argues that he will only "ask" the slave questions and not "teach" him, it can be inferred that Socrates perceives of questioning as distinct from teaching. In this respect, teaching amounts only to the transmission of knowledge from teacher to student. Since Socrates does not "teach" the slave anything, all the geometry knowledge that the slave appears to have must come from his own head and must reside in there too. Socrates was primarily concerned with finding the source of that knowledge, determining how it got into the slave's head. Regardless of how acceptable Socrates' explanation is today, the point is that with the means of

questioning a teacher can frame an activity such as problem solving, orient his students towards a goal, focus his students' attention to specific and important features of the task, induce his students' thinking along certain lines of thought, help his students evaluate the goals set, and control students' cognitive processing. Through questioning, Socrates provides both a goal and the means to achieve that goal, regulating and guiding the slave's thinking. Thus, questioning constitutes nothing but a scaffold that is provided by the teacher and used by the student.

Furthermore, by responding to the questions posed by Socrates, the slave fills in certain slots in the dialogue, that is, makes use of the scaffold to carry out a mental act. Filling in slots requires thinking and the slave does think for otherwise he would not have been able to respond in an intelligible way. The outcome of his thinking, though, the cognitive product, is not his alone for it was induced by specific questions and can only have meaning as a response to those questions. Because the responses are dialogically related to the questions, the thinking that the responses require is also dialogically linked to the questions. Therefore, the cognitive processing that led to a certain piece of geometrical knowledge cannot be attributed to the slave alone: it was essentially distributed. The slave participated in a social interaction with a more knowledgeable person (Socrates) and was able to reach an understanding of a geometrical relation only in the course of such an interaction, as a result of regulation and guidance from the expert member. It should also be stressed that language and other representational tools (e.g., drawings) were employed in the interaction. The outcome of the interaction was heavily dependent on and influenced by the use of such cognitive artifacts.

To sum the argument up, the original question posed to Meno by Socrates: "*were not all these answers given out of his own head?*" is misleading. Even though Socrates attributes the thinking to the independent mental activity of the young slave, it is in fact the Socrates-slave dyad that jointly performed the respective cognitive processing. Moreover, the cognitive processing was effected with the aid of certain cognitive artifacts and representational tools, such as language and drawings. From a distributed cognition point of view, a more appropriate question to ask would be: "*were not all these answers given out of his own head but with the help of the questions asked and the drawings made?*"

The question of how cognition is distributed has been treated separately here, as an independent issue of cognition. It should be born in mind, however, that distributed cognition represents an approach that highlights certain facts about cognition and is merely a sub-issue of the general problem of cognition and cognitive development. Even though distributed cognition has proponents in various cognitive traditions (e.g., cognitive science,

educational psychology, socio-cultural psychology-cultural-historical psychology, and cultural-historical activity theory), a unified approach is not foreseeable in the future due to the important differences in terms of how cognition is conceived in these traditions. Nevertheless, we find it promising that researchers in diverse psychological traditions are coming to terms with the realization that the conception of cognition as being located (only) in the head, without reference to body, tools, and the overall context is a highly inappropriate one.

References

Clark, A. (1997). *Being there. Putting brain, body, and world together again*. Cambridge, MA: MIT press.

Cobb, P. (1998). Learning from distributed theories of intelligence. *Mind, Culture, and Activity*, *5*(3), 187-204.

Cole, M., & Engestrom, Y. (1993). A cultural-historical approach to distributed cognition. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 1-46). New York: Cambridge University Press.

Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.

Dreyfus, H.L., & Dreyfus, S.E. (1990). Making a mind versus modeling the brain: Artificial intelligence back at a branch-point. In D. Lycan (Ed.), *Mind & cognition* (pp. 309-333). London: Blackwell.

Gardner, H. (1987). *The mind's new science: A history of the cognitive revolution*. New York: Basic Books.

Greeno, J., & Moore, J.L. (1993). Situativity and symbols: Response to Vera and Simon. *Cognitive Science, 17*(1), 49-59.

Hatch, T., & Gardner, H. (1993). Finding cognition in the classroom: An expanded view of human intelligence. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 164-187). NY: Cambridge University Press.

Haugeland, J. (1998). *Having thought: Essays in the metaphysics of mind*. Cambridge, MA: Harvard University Press.

Heath, S.B. (1991). "It's about winning!" The language of knowledge in baseball. In L.B. Resnick, J.M. Levine, & S.D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 101-124). Washington, DC: American Psychological Association.

Hutchins, E., & Klausen, T. (1998). Distributed cognition in an airline cockpit. In Y. Engestrom & D. Middleton (Eds.), *Cognition and communication at work* (pp. 15-34). New York: Cambridge University Press.

Hutchins, E., & Palen, L. (1998). Constructing meaning from space, gesture and speech. In L.B. Resnick, R. Saljo, C. Pontecorvo, & B. Burge (Eds.), *Discourse, tools, and reasoning: Essays on situated cognition* (pp. 23-40). NY: Springer-Verlag (NATO ASI Series F, vol. 160).

Hutchins, E. (1991). The social organization of distributed cognition. In L.B. Resnick, J.M. Levine, & S.D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 283-307). Washington, DC: American Psychological Association.

Hutchins, E. (1995a). *Cognition in the wild*. Cambridge, MA: MIT press.

Hutchins, E. (1995b). How a cockpit remembers its speeds. *Cognitive Science, 19*(3), 265-288.

Karasavvidis, I. (1999). *Learning to solve correlational problems: A study of the social and material distribution of cognition*. Unpublished Doctoral Dissertation, University of Twente, The Netherlands. Available:
http://www.ub.utwente.nl/webdoc/docs/to.shtml

Lave, J., Murtaugh, M., & de la Rocha, O. (1984). The dialectic of arithmetic in grocery shopping. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 67-94). London: Harvard University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. New York: Cambridge University Press.

Lave, J. (1991). Situating learning in communities of practice. In L.B. Resnick, J.M. Levine, & S.D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 63-83). Washington, DC: American Psychological Association.

Luria, A.R. (1928/1994). The problem of the cultural behavior of the child. In R. van der Veer & J. Valsiner (Eds.), *The Vygotsky reader* (pp. 46-56). Cambridge, MA: Blackwell.

Moll, L.C., Tapia, J., & Whitmore, K.F. (1993). Living knowledge: The social distribution of cultural resources for thinking. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 139-163). New York: Cambridge University Press.

Nardi, B.A. (1996). Concepts of cognition and consciousness: Four voices. *Australian Journal of Information Systems, 4*(1), 64-79.

Norman, D. (1993). *Things that make us smart: Defending human attributes in the age of the machine*. Reading, MA: Addison-Wesley.

Pea, R.D. (1993). Practices of distributed intelligence and designs for education. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 47-87). New York: Cambridge University Press.

Perkins, D.N. (1993). Person-plus: A distributed view of thinking and learning. In G. Salomon (Ed.), *Distributed cognitions. Psychological and educational considerations* (pp. 88-110). NY: Cambridge University Press.

Resnick, L. (1991). Shared cognition: Thinking as social practice. In L.B. Resnick, J.M. Levine, & S.D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 1-20). Washington, DC: American Psychological Association.

Resnick, L.B., Levine J.M., & Teasley S.D. (1991). *Perspectives on socially shared cognition*. Washington, DC: American Psychological Association.

Rogoff, B. (1991). Social interaction as apprenticeship in thinking: Guidance and participation in spatial planning. In L.B. Resnick, J.M. Levine, & S.D.

Teasley (Eds.), *Perspectives on socially shared cognition* (pp.349-364). Washington, DC: American Psychological Association.

Saljo, R. (1999). Learning as the use of tools: A sociocultural perspective on the human-technology link. In K. Littleton & P. Light (Eds.), *Learning with computers: Analyzing productive interaction* (pp. 144-161). London: Routledge.

Salomon, G. (1993). *Distributed cognitions: Psychological and educational considerations*. New York: Cambridge University Press.

Salomon, G. (1993a). Editor's introduction. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. xi-xxi). New York: Cambridge University Press.

Schegloff, E.A. (1991). Conversation analysis and socially shared cognition. In L.B. Resnick, J.M. Levine, & S.D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 150-171). Washington, DC: American Psychological Association.

Vygotsky, L.S., & Luria, A.R. (1994). Tool and symbol in child development. In R. van der Veer & J. Valsiner (Eds.), *The Vygotsky reader* (pp. 99-174). Cambridge, Massachusetts: Blackwell.

Vygotsky, L.S. (1960/1981a). The instrumental method in psychology. In J.V. Wertsch (Ed. & Trans.). *The concept of activity in Soviet psychology* (pp. 134-143). Armonk, NY: M.E. Sharpe.

Vygotsky, L.S. (1960/1981b). The genesis of higher mental functions. In J.V. Wertsch (Ed. & trans.), *The concept of activity in Soviet psychology* (pp. 144-188). Armonk, NY: M.E. Sharpe.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes.* M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds. & Translators). Cambridge, MA: Harvard University Press.

Vygotsky, L.S. (1987). The collected works of L.S. Vygotsky, Vol. 1. In R.S. Rieber & A.S. Carton (Eds.); N. Minick (Trans.), *Problems of general psychology*. New York: Plenum Press.

Wertsch, J.V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. London: Harverster-Wheatsheaf.

Wertsch, J.V. (1998). *Mind as action*. New York: Oxford University Press.

Winograd, T., & Flores, F. (1987). *Understanding computers and cognition: A new foundation design*. Boston: Addison-Wesley.

Zhang, J., & Norman, D.A. (1994). Representations in distributed cognitive tasks. *Cognitive Science, 18*(1), 87-122.