Of Landscapes, Anchors, and Tools: on learning with multimedia computer programs

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ABSTRACT Under the cognitive paradigm human learners are portrayed as information processing systems. The idea of looking upon human beings as computers certainly seems to be progressive if one bears in mind that under the behaviourist paradigm, human learners are treated as black boxes, but it still leaves something to be desired. In recent instructional studies, the capacity of this approach to account for learning outcomes has therefore been questioned, arguing that processes of cognition and learning are basically situated, i.e. are based on an individual's activities in a social situation. The idea of cognition being situated has had some influence on theoretical approaches that have been developed in the field of learning and instruction with multimedia computer programs. Interestingly, a number of images or metaphors can be found in the writings of the respective authors that are used to characterise certain aspects of knowledge and knowledge acquisition processes: landscapes, anchors, and tools. I would like to have a closer look at these metaphors and then use them to help charter the territory of learning and instruction with multimedia computer programs.

Introduction

Cognitive psychology looks upon the learner as an information processing system. It is assumed that the incoming information is processed at various levels and finally stored into long term memory as knowledge. There are a number of models that are used to depict the structure of that knowledge, and there are many studies that show that the structure of an individual’s knowledge, or more specifically, the units of that structure (such as schemata or scripts) not only influence processing of incoming information, but also processes of knowledge retrieval or reconstruction from long term memory. The modelling of learning processes as processes of knowledge acquisition within a framework of an information processing approach seems much stronger than the models and their theoretical explanations that were developed under the behaviourist paradigm.
The metaphor of human beings as information processing systems has, however, severe shortcomings. Computers are machines, human beings are not. Certainly, they do process information, but the knowledge they finally store into long term memory is not the results of a program that is being executed, it is the result of active construction on the part of the learner. That is, it is assumed that if learning is a process of knowledge acquisition, this process is one of actively constructing this knowledge as a mental representation of the outside world (for a discussion of constructivism as related to learning theory and computer based instruction see for instance Duffy & Jonassen, 1991, 1992; Dinter & Seel, 1994; Gerstenmaier & Mandl, 1995), and it is also assumed that this construction is a social process, i.e. that it results from interaction with other people (see, for instance, Vygotsky, 1978).

Some time ago, Allan Collins pointed out that the way we perceive and understand the world and the manner in which we learn is not independent of the situation in which we do this, i.e. cognition and learning are situated (Brown, Collins, & Duguid, 1989a). In considering knowledge as a set of tools, he proposes that to acquire knowledge does not mean to be given a set of tools, it means to learn how to use these tools in the culture where they are customarily used.

The idea of situated cognition has also had its impact on approaches that focus on the construction of knowledge with the help of multimedia computer programs. Spiro and his colleagues, in their theory of cognitive flexibility, compare knowledge to a landscape that needs to be criss-crossed in order to be fully understood. Whereas, Bransford and his colleagues, from the Cognition and Technology Group at Vanderbilt University (CTGV), have suggested that instruction should be anchored in specific situations that arouse students' interest in solving problems contained in the anchoring situation. Finally, the metaphor of a tool is being taken up by Salomon who claims that computer programs may be used as cognitive tools.

**Knowledge as a Tool**

According to the Encyclopaedia Britannica (1987, Vol. 28, p. 712) a tool is “an implement or device used directly upon a piece of material to shape it into desired form”. As Salomon (1993) has pointed out, this definition needs a number of clarifications:

- First, a tool need not be a real object; it may be a symbol system, a mental strategy, or a computer program, nor is it necessary that the piece of material be really material. The aforementioned tools may be used in communication processes, mental representations of problems, and on symbol systems, respectively.

- Second, a tool is a device that has been developed within a specific culture as a tool; its proper uses are culturally defined and transmitted.
Third, tools are used for specific purposes, to reach particular goals, i.e. they serve functions beyond themselves.

Fourth, a tool is not a machine. Machines are more or less autonomous, while tools need to be skilfully operated.

Collins has argued that conceptual knowledge may be looked upon as a set of tools. To understand how a tool works, one has to actually use it, and this implies, according to Collins, that it is necessary to enter the culture in which it is used and to adopt its belief system. The ordinary practices of a culture are, from Collins’ point of view, authentic activities, and anyone willing to learn to use a certain tool does so by observing authentic behaviour in a specific culture (Brown et al., 1989a; see also Palincsar, 1989, and Wineburg, 1989, for a critique, and Brown et al., 1989b, for a reply).

At first glance, the metaphor of knowledge as a tool, i.e. as a device that is being used in a given culture to reach a specific goal, seems to be very intriguing. Collins’ concept of culture has, however, met with some criticism. Palincsar (1989), for example, has argued that it may be impossible to have students participate in all the different cultures that might be of importance to them, and it might not even be desirable. She also makes the point that it is possible to use a tool meaningfully without belonging to, or even knowing the culture where the tool originated. Wineburg (1989) has seconded this idea by referring to the American historian Barbara W. Tuchman whose books are read and appreciated by millions of readers the majority of whom probably are not members of the culture of academic historians.

This last one certainly is an interesting argument. We may assume that professional historians and Just Plain Folks, as Collins calls the men on the street, are employing different sets of tools when they read a historical text. The average reader may find Barbara Tuchman’s interpretation of historical events convincing and therefore enjoy her books, while the professional historian may want to read the sources Tuchman used when writing one of her books in order to come up with an interpretation of his own.

The most significant argument with respect to culture seems to be, however, that according to Collins, school has developed a culture of its own that is very different from the culture of those disciplines with which it intends to acquaint its students. It is therefore likely that the knowledge that students acquire in school is of little use in solving real problems in any of the cultures that exist outside the school. School knowledge cannot be used as a tool.

Inert Knowledge

The idea of thinking about conceptual knowledge as a set of tools implies a view of knowledge as something useful. In contrast knowledge that is not being used remains inert, to use a term that was coined by Whitehead
(1929) and is now cited frequently. Schoenfeld (1985), for example, in analysing how students solve mathematical problems, observed that many students do have the required knowledge, but since they do not perceive this knowledge as being useful to them, they do not call upon it. Renkl (1996) has recently provided a thoughtful analysis of the phenomenon, referring to meta-process, structure deficit, and situatedness of explanations. A major part of the discussion in instructional research at present centres on the question of how to avoid transmitting knowledge that remains inert, that is unused by students.

**Cognitive Apprenticeship**

Collins considers learning as a process of enculturation and suggests that it may occur in a way that is similar to learning a specific trade. To view the acquisition of knowledge and skills as a process of cognitive apprenticeship means that first, there is a master or expert who models authentic activities that the learner (the apprentice) is to acquire (modelling). In the second stage, the learner will start to participate in these activities, but under the supervision of the expert (coaching). In the third stage, the learner will be largely on his own, but the expert will still be there to provide help should it be needed (Collins et al, 1989).

To give substance to his idea of cognitive apprenticeship, Collins reviews the works of Palincsar and Brown (1984) on the use of reciprocal teaching to enhance reading comprehension; of Scardamalia & Bereiter (1985) on the procedural facilitation of writing; and of Lampert (1986) and Schoenfeld (1985) in the field of teaching mathematics.

**Metacognition: knowing how and when to use a tool**

All the studies reviewed by Collins show that students do indeed benefit from instruction that includes modelling the behaviour in question and giving them the opportunity to imitate this behaviour with the possibility to be corrected by the model. However, what seems to be important in this context is that, in all of these studies, modelling includes the explicit use of metacognitive activities that are then being trained in the coaching phase.

During the last decade, it has become increasingly clear that metacognition plays a vital part in learning and problem solving processes. The term was coined by Flavell (1971) and pertained to knowledge about one's own knowledge and to metacognitive experience. It has become customary to distinguish between metacognitive knowledge and metacognitive skills, i.e. self-regulatory processes that include analysing the given task, developing a plan of how to proceed, implementing the plan, and monitoring and evaluating its execution. With respect to the metaphor of knowledge as tool, to acquire metacognitive skills would mean to learn how
and when to use a specific tool. As far as teaching is concerned, this reminds us that it is not sufficient to present our students with a set of tools, we also will have to show and to train them how to make intelligent use of them.

There are a number of instruction studies that show that metacognitive skills may be taught and that the acquisition of these skills turns out to be extremely beneficial. Some of the most impressive data on the effectiveness of teaching metacognitive skills come from one of the studies reported in Palincsar & Brown (1984). To improve students’ monitoring of text comprehension, they were instructed to (1) summarise paragraphs, (2) to ask questions about each paragraph, (3) to clarify ambiguities, and (4) to make predictions about succeeding paragraphs.

In a similar study (Palincsar, 1986), students were working from the following text:

Crows have another gift. They are great mimics. They can learn to talk and imitate animal sounds. Some have been known to learn 100 words, and even whole phrases. They can imitate the squeak of a chicken, the whine of a dog, or the meow of a cat.

Games have a certain fascination to crows. In a game of hide-and-seek, a crow hides in the hollow of a tree and then sounds a distress caw. The others rush to the spot, look around, then flap away. This may be done over and over, after which the young crow pops out of his hiding place and caws gleefully. Far from being annoyed at this, the flock bursts into loud cawing themselves. They seem to like the trick that has been played on them.

Part of the ensuing dialogue between the teacher and her students is given below:

T: Chantel, you’re the teacher, right? Why don’t you summarise first? Remember, just tell me the most important parts.
S1: Crows have a hundred words they can learn by imitation. They can imitate chickens, the whine of a dog, and cats.
S2: You could say the imitate other animals.
T: Oh! Good one! There’s a list there, Chantel, did you notice that? It says they can imitate the squeak of a chicken, the whine of a dog or the meow of a cat; and you could call that “animal sounds”. Can you ask a question?
S1: Ain’t no question in here.
S3: The words (sic.) that need to be clarified are (sic.) “mimics”.
S4: That means imitate, right?
T: Right. How did you figure that out, Shirley?
S4: The paragraph.
T: Show us how somebody could figure out what “mimic” means.
S5: They are great mimics. They can learn to talk and imitate animal
sounds.
T: Yes, so the next sentence tells you what it means. Very good, anything else needs to be clarified?
All: No.
T: What about the question we need to ask? (pause). What is the second paragraph about, Chantel?
S1: The games they play.
S3: They do things like people do.
S4: What kind of games do crows play?
S3: Hide and seek. Over and over again.
T: You know what, Larry? This was a real good comparison. One excellent question could be, “How are crows like people?”
S4: They play hide and seek.
T: Good. Any other question there?
S2: How come the crows don’t get annoyed?
S5: What does annoyed mean?
T: Irritated, bothered.
S5: Because they like it, they have fun. If I had a crow, I’d tell him he was it and see what he’d do.
T: Let’s summarise now and have some predictions.
S1: This was about how they play around in games.
T: Good for you. That’s it. Predictions anyone?
S2: Maybe more tricks they play.
S4: Other games.
T: Maybe. So far, they have told us several ways that crows are very smart: they can communicate with one another, they can imitate many sounds, and they play games. Maybe we will read about another way in which they are very smart. Who will be the next teacher?
(Palinscar, 1986, pp. 121-122)

The training was done in a reciprocal teaching setting, i.e. the teacher exchanged her role with the students after first having modelled the appropriate metacognitive strategies. After a three-week training period, students’ reading comprehension scores improved from 15 % correct (pre-test) to 85 % correct (directly after the training). Even after a period of six months, students from the experimental group averaged 60 % correct, and it took only one day of renewed reciprocal teaching to bring them back to their 85 % correct level. Also, effects generalised from the experimental to the classroom setting, and there was a clear and reliable transfer to laboratory tasks that differed in surface features from the training task.

There is evidence from other sources that metacognitive skills are of great importance in learning and problem solving processes and may indeed be taught. De Jong & Simons (1990) completed four studies to find out if students could be trained to become active learners. The training, however, was only partially successful, and they discuss a number of factors that
might have impeded active learning. Moore (1993), on the other hand, found that metacognitive processing of diagrams, maps, and graphs may be fostered in the context of a reciprocal teaching training programme. Eteläpelto (1993) compared experts and novices with respect to computer program comprehension. He found that experts show a close interaction between metacognitive knowledge, task-specific awareness and cognitive monitoring which novices did not. Volet & Lund (1994) instructed target students to use metacognitive strategies in computer programming and found that this kind of instruction was a better predictor of success than traditional variables such as background knowledge, main course (major course), gender or age.

Learning and Multimedia Computer Programs

In the last couple of years, two approaches to explain learning processes as they are initiated by multimedia computer programs have evolved that are examples of constructivists theorising and that also refer to Collins’ ideas on situated cognition. These are cognitive flexibility theory as developed by Spiro and his colleagues at the University of Illinois (Spiro & Jehng, 1990; Spiro et al, 1991a,b) and the anchored instruction approach as proposed by Bransford and his colleagues from the Cognition and Technology Group at Vanderbilt University (Bransford et al, 1990; CTGV 1990; 1991a,b; 1993). I am also including the work of Salomon (1993) on a program that helps to write a story, although it is not a multimedia program in the narrow sense.

Knowledge as Landscape and Cognitive Flexibility Theory

According to Spiro, the traditional approach to teaching is insufficient. Textbooks have the tendency to simplify problems and to offer set solutions. Simplified solutions may, however, make it difficult for students to achieve an understanding of highly complex phenomena. Referring to an image first put forward by Wittgenstein (1953), he compares knowledge to a landscape. In order to acquaint oneself with this landscape, one has to traverse it many times in different directions, one has to criss-cross it. Acquiring knowledge then means to construct a mental structure from different conceptual and case perspectives. This requires providing the learner with a flexible learning environment, and to Spiro, there is no doubt that multimedia computer program can do this best.

The metaphor of knowledge as a landscape is an intriguing one. Much of our knowledge is complex and ill-defined, and it will not help students understand if they are served this knowledge in little bits and in a very orderly manner. As Spiro points out, this simplifying procedure may even hinder them in coming to a good understanding. Giving them the opportunity to explore the complex terrain thoroughly is likely to give them a good grasp of it, and there is nothing in the metaphor that forbids us to
provide them with an experienced guide that will help them in this
endeavour.

The basic idea of cognitive flexibility theory as developed by Spiro and
his colleagues is that processing complex information may not be achieved
by the activation, modification and possibly creation of complete schemata.
An adequate processing of complex information requires cognitive flexibility
in the sense that the student has to be able to activate partial schemata and
to combine these into complex new ones.

In one of the empirical studies that Spiro conducted, a hypertext
program was used to acquaint students with the social consequences of the
new technologies. The result of this experiment revealed that while the
design which emphasised the mastery of declarative knowledge led to higher
performance on measures of memory for presented facts, the design based
on Cognitive Flexibility Theory (which highlighted different facets of the
material by explicitly demonstrating critical interrelationships between
abstract and case-centred knowledge components, in multiple contexts on
different passes through the same content) promoted superior transfer to a

Practically the same results were obtained in another experiment run
by Jacobson & Spiro (1995). The experimental group that worked in a
hypertext learning environment based on cognitive flexibility theory showed
superior knowledge transfer, while the control group scored higher in
memory for factual knowledge. Positive results are also reported in a study
by Brown (1995) who used the cognitive flexibility approach to construct a
hypertext environment to teach students the use of electronic mail.

Anchored Instruction

The work of Bransford and his colleagues is motivated by the desire to
tackle the problem of inert knowledge, and much like Collins, they realise a
solution might have to involve ideas that originate with the concept of
situated cognition.

The major goal of anchored instruction is to overcome the inert
knowledge problem. Bransford and his group attempt to do so by creating
environments that permit sustained explorations by students and teachers
and enable them to understand the kinds of problems and opportunities that
experts use as tools. They also attempt to help students experience the value
of exploring the same setting from multiple perspectives (e.g., as a scientist
or historian) (CTGV, 1990, p. 3).

The idea is that in order to avoid the inert knowledge problem, it is
necessary to anchor the knowledge that the students are supposed to
acquire in a specific setting that arouses their interest. Getting interested in
the problem may make students interested in looking for tools they might
use in to solve the given problem.
Of course, even a written text might serve as an anchor. Bransford prefers to work with interactive video because he believes that a video-based anchor contains much richer sources of information, that the presentation of dynamic, moving events will facilitate comprehension to a higher degree, and that presenting knowledge embedded in a sequence of video scenes will conditionalise this knowledge, i.e. anchor it to specific ‘triggering conditions’ (Bransford et al, 1990).

Bransford reports advantages of anchored instruction over traditional instruction. In one study relating to historical knowledge, students obtained higher values in story writing, vocabulary use and acquisition of relevant knowledge of history in the anchored instruction setting. In another study, students working with interactive video showed markedly better transfer with respect to complex problem solving than a control group (CTGV, 1993).

Computer Programs as Cognitive Tools

There exists another metaphor that contains the image of a tool: the metaphor of a cognitive tool, i.e. a tool that may help students accomplish cognitive tasks (Pea, 1985; Perkins, 1985; Salomon, Perkins, & Globerson, 1991). According to Lajoie (1993), four types of cognitive tools may be identified:

- tools that support cognitive and metacognitive processes;
- tools that share the student’s cognitive load by providing support for lower level cognitive activities so that the student may concentrate more on higher level cognitive activities;
- tools that allow the student to engage in cognitive activities that otherwise would be out of his reach (to provide a zone of proximal development, in Vygotskian terminology);
- tools that make it possible for the student to generate and test hypotheses in problem solving activities.

Since computer programs in general may be considered cognitive tools, this also applies to multimedia computer programs. Of course, two or more functions may be served by the same program. Salomon (1993), in taking up the metaphor of the computer program as a cognitive tool, further distinguishes between performance-oriented tools and pedagogical tools. While the former help the learner in a given situation to improve his or her actual performance, the latter aim to help the students acquire and cultivate generalisable skills, particularly higher order thinking skills that later on may be employed in the absence of the tool. An example of the former kind would be a word processor, an example of the latter kind Salmon’s Writing Partner, a computer program that helps students write a creative story.

The Writing Partner program is based on the psychological analysis of composition writing by Bereiter & Scardamalia (1987), on their theory of procedural facilitation (Scardamalia et al, 1989), on Vygotsky’s (1978)
socio-historical theory of development, and on the author’s theory of technology and mind (Salomon, 1990). It is designed to help students shift from writing composition in the free-association, less-than-thoughtful mode of ‘knowledge telling’ to writing better planned, self-guided, self-diagnosed and revised compositions of the ‘knowledge transformation’ mode (Salomon, 1993, p.185).

The program offers four types of assistance (procedural facilitations) to the student:

x The student is guided through a forced process of planning of his or her story, brainstorming and outlining.

x While writing, students can ask for assistance which will be given to them in the form of expert-like questions that depend on the key-words typed earlier in the composition.

x Once the student does not know how to continue his or her story (“I am stuck”), the program will help the student diagnose where and with what she or he is stuck (Opening, Lost the main idea, Plots don’t meet, Need a word, etc.).

x Finally, the student’s ideas that he downloaded from his mind into the program (idea list and outlines) may be retrieved at any time during the writing process.

The uniqueness of the tool lies in the expert-like guidance, itself based on relevant research, that it affords before and during the process of writing. It does not teach writing nor does it correct errors (hence it does not need to be highly intelligent). It is based on the assumption that students are the ones who need to do the thinking (planning, self-diagnosing, self-guiding) and that the tool ought only to provide them with the stimulation and guidance for doing so. In this sense it appears to be a genuine pedagogical tool (Salomon, 1993, p. 187).

Evidently, the metaphor of knowledge as a tool and that of a computer program as a cognitive tool share the basic idea of a tool being a device to accomplish a task. The difference is that in the first case, we may think of the tool as an internal (mental or cognitive) device, while in the second case, the tool is an external device (with the power to support internal processes). From this point of view, calling computer programs cognitive tools seems not to be a good idea: they are not really cognitive, they are tools being used in cognitive activities. Of course, we might ponder on the question whether knowledge, if it is to be used as a tool, has to be internal. It may not have to be in long-term memory, but I think it must be somewhere on the student’s mind in order to be usable as a tool.

Metacognition, finally, would refer to one’s awareness of the different kinds of tools that one has to hand (or preferably at one’s fingertips) and to one’s competence in choosing those which are best suited for a given task and applying them intelligently.
Conclusion

To me, the metaphor of knowledge as a (cognitive) tool has something very convincing about it. If we want to understand the phenomena of the world we live in, if we have to cope with problems in everyday life, knowledge may be of help. The same applies to processes of knowledge acquisition and problem solving in the classroom, even if we concede that the culture of the school if different from other cultures outside the school. To teach then, not only means to provide students with a tool kit, it also becomes necessary to show them and training them how and when to use these tools.

There is another interesting point concerning tools: we generally look for a tool when we have a problem, when we want to repair something or construct something new. In school, the situation sometimes is the other way around: students are given a tool, and there is no real or only a highly artificial and very simplified problem. The anchored instruction approach tries to overcome this difficulty by creating problem situations that make students look for adequate tools.

The metaphor of knowledge as a tool that needs to be operated skilfully challenges the cognitive paradigm of people as information processing systems. Learning is more than information processing; it most certainly involves cognitive processes, but it is also based on activities carried out in social setting (it is situated), and it requires metacognitive activities as well. As Renkl (1996), in his analysis of the inert knowledge problem, has pointed out, the fact that knowledge remains inert may not only be a problem of insufficient metacognitive skills or of defects in the knowledge representation, it may also be attributed to motivational and volitional deficiencies. A thorough analysis of learning processes that are initiated and supported by multimedia computer programs would have to take these factors into account, too.

As for multimedia computer programs, to me there is no doubt that they may serve as tools in knowledge acquisition and problem solving activities. Certainly, they are no cure-all, they are not the super mega power tools that help solve each and every problem. Evidence from empirical research is still somewhat inconclusive. There are no general effects; instead, a number of aptitude treatment interactions have been found (Rouet, 1992, 1994; Balcytiene, 1995; Britt et al, 1995). On the other hand, there are studies that clearly demonstrate that using a multimedia computer program as a tool will effectively support learning processes. The research of Bransford and Spiro and their respective colleagues are cases in point.

Furthermore, if we really think that constructivism is a valid paradigm, one way of fostering constructive skills would be to allow students to construct “objective” and socially shared knowledge by giving them the opportunity to develop multimedia computer programs (see Lehrer, 1993).
Finally, although it does make sense to study the cognitive processes of students who are working with a multimedia computer program, the question to what extent this tool really supports learning will have to be examined in a larger context and in a natural setting, in a classroom, for example, where the program is part of an instructional sequence. As Salomon points out: “No tool is good or bad in and of itself; its effectiveness results from and contributes to the whole configuration of events, activities, contents, and interpersonal processes taking place in the context of which it is being used.” (1993, p. 186).

The ImpacT Report (Watson, 1993) which evaluates the impact of information technology on children’s achievements in primary and secondary schools in the UK may be cited as a good example of this kind of ‘situated research’. One of its main findings is that: “the nature of the use, exploratory or inquiry focused, indicated that the use of IT which provides pupils with opportunities to take decisions and make choices promoted higher level learning outcomes” (p. 4).

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