

The Dual Memory Systems Model and it's implications for Technology Education.

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Abstract

This paper examines the relationship between the explicit and the implicit memory and learning systems in terms of recent findings in neuropsychology and outlines the implications for technology education in terms of student learning.

The psychological Dual Systems Theory situates the processing of perception, assessment, decision-making and action in two parallel but different cognitive systems. The Declarative/Explicit system is conscious, remembering facts and episodes; it is rational and logical but also limited in complexity and speed. Working Memory's (WM) capacity, an "end station" of this system, is severely limited. Depending on modality between 4 and 9 variables or steps in a sequence may be handled at once. More will lead to cognitive loading and impasse. Since WM probably is our consciousness, we will not be able to analyse what was dropped out or what happened, we will just get confused. The narrow view of conscious vision, the slow speed and the problems with details and complexity in space and time makes this system less suitable for real time, real complexity work.

The non conscious Implicit System on the other hand does not use Working Memory and will not be hampered by cognitive overload; it's a pattern recognition system with very fast recognition of earlier encountered situations and objects. It has several important functions:

- 1- *To direct conscious attention to what is important and relevant in a situation.*
- 2- *To give a fast assessment, built upon somatic markers incorporated in memory.*
- 3- *To start an automatic reaction to what is perceived,*

The lifespan of this memory system is long, and it seems very hard to erase or to change them. Most of what we usually refer to as skill seems to be connected to learning in this system. The Dual Systems model has recently been supported with neurophysiologic results showing, two different anatomical systems. The somatic markers have been identified, the secondary implicit vision system and concepts such as tacit knowing, automaticity, flow and intuition are starting to be understood. This model gives a new way of understanding what we do in technology education, gives clues of how to promote creativity, holistic learning, system thinking, forward reasoning and more.

Introduction

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Objects in Natural environments as well as in the Constructed world consist of many features on different scale levels. The wood is composed by plants, for example trees, bushes and flowers and many other objects and animals. A technological artefact, for example, the mobile phone system consists of many electronic components and computer software interplaying in a complex way to make it possible to communicate with someone in another place on earth. However, the wood, as a whole, is not possible to see if we only look at the trees. In the same way is the mobile phone system not discernable just by focusing on its components. How do we achieve holistic top- down observational skills? Research has shown that humans are rapid in categorizing natural scenes, using global properties (Greene & Oliva, 2009). For example, humans are able to discern a lake from a wood without effort, an ability which has been hard to replicate by a computer. People engaged in and with long time experience of a technological system seems to be able to understand and handle it without any problem. These findings suggest that the ability to categorize a system is connected with an *observational skill*, something that can be learned. The purpose of this paper is to describe and suggest an explanation for expert teachers' ability to attend to essential details in a complex environment without losing the overview of the system. To do this we have used and refined a psychological dual memory system model for human behaviour and learning. Empirical data from outdoor Biology teaching were analysed using this model and we also want to show similarities between Technology education and this branch of natural science. These two school subjects share the task of describing and analysing complex systems, structure, functions and behaviour. Implications for teaching in general as well as technology education are discussed.

Research on observational skills

Teachers' observational skills in classrooms have been studied for many years. Expert teachers have a better ability to read cues from pupils in the classroom than novice teachers (Berliner, 2001). Kerrins and Cushing (2000) have also identified differences between experts and novices observing the same classroom. In a stimulated recall setting, experienced and beginning principals viewed a teaching episode and were then asked questions about what happened in the classroom. The main difference between the novices and the experts was that the experts tended to observe the classroom from a broader, interpretative perspective, whilst the novices tended to be more descriptive in their approach, missing the connectedness and coherence. Another study reported that expert teachers were more receptive to both visual and auditory stimuli than novice teachers (Sabers, et al, 1991). The participants of the study viewed three video monitors, each showing a separate view from a classroom group work. The experts scanned all three monitors for meaningful events, while the novices were only able to look at one of the screens at a time. These studies do describe how the observational skill develop with experience, but they do not offer an explanation on why this happens, and how. In a recent study, Ainley and Luntley (2007) suggest that "attention-dependent knowledge" helps the teacher to focus on what is important in a particular situation and what needs to be evaluated and acted upon. The authors also emphasize that this knowledge is neither reflected nor possible to verbalize, that is, it is tacit. Johansson and Kroksmark (2004), confirmed that experienced teachers had this skill and found several examples of automatic behaviour in the classroom, a skill which they described as "intuition-in-action". The experts intuitive, tacit skill in recognising what is good or bad was

described by Donald Schön (1987) *“Not only in artistic judgement but in all our ordinary judgements of the qualities of things, we recognise and describe deviations from a norm very much more clearly than we can describe the norm itself”*.

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It seems like expert teachers have a holistic overview of the classroom, instead of focusing on details. They also have an enhanced ability to attend to relevant aspects in the classroom. Thereby, the experienced teachers are able to manage the classroom with little effort. Novice teachers, however, tend to have difficulties in their teaching since they are busy sorting out which details they should attend to.

The expert teachers seem to act fast and react appropriately in upcoming situations. Noticeably, these actions are automatic, not reflected and even non-conscious. They have an ability to attend to meaningful events in complex and busy environments.

The skills that discern a novice from an expert could be explained in terms of a psychological dual-processing model of cognition (Björklund, 2008; Evans, 2008). The starting point for the present paper was the assumption that the dualistic psychological model could be used to explain experts' observational skill in a complex environment.

A Dual Memory System Model to explain the Development of Expertise

Dual-processing is a psychological model which implies that there are two different systems for reasoning, judgement and social behaviour (Evans, 2008). Recent research in the fields of cognition and neuropsychology have confirmed that there are two biologically distinct memory systems in the human brain, the declarative and the non-declarative systems (Evans, 2008; Squire, 2004). By integrating results from research in psychology, physiology and pedagogy, Björklund suggests that the dual memory system model is applicable for research on learning (Björklund, 2007, 2008). He uses the terms implicit and explicit memory systems as synonyms for the non-declarative and declarative systems, respectively.

The explicit memory system is a conscious, analytic and reflective system which deals with episodes, rules and sequences (Evans, 2008). When people are trying to categorize an unknown object using this system they use logical rules, looking for characteristics and typical details. This systematic approach suggests that objects are identified through feature-by-feature matching against a generic example (Norman, et al, 2007). In doing so, there are many details or units that need elaboration. This process uses the Working memory. However, Working memory has a limited capacity (Marois & Ivanoff, 2005). With more than four variables to process at a time Working memory will be cognitively overloaded (Ross, 1969; Sweller & Chandler, 1991). Thereby, the explicit memory system is limited by the low capacity of Working memory (Lieberman, et al, 2002; Marois & Ivanoff, 2005). These limitations make it hard, or even impossible, to cope with real time, complex situations. Another constraint for the explicit memory system is its use of the conscious vision. We are only able to focus on a small area, just one detail at a time, since conscious vision is very narrow (Bullier, 2001; Milner & Goodale, 2008). To take in a wider view we need to consciously move our sight from one object

to the next, which takes time. Research on change blindness has shown that we easily miss even large objects in front of us (Simons & Chabris, 1999). One advantage of the explicit memory system is that it is possible to verbalize and communicate explicit knowledge. Since it is based on rules it is possible to be used by novices and be taught (Dreyfus & Dreyfus, 1986).

Fortunately, the explicit system is not the only system available. Humans also have an unconscious, non-declarative system, the implicit memory system (Berry & Dienes, 1993). This is a rapid, automatic, holistic system using pattern recognition (Evans, 2008; Lieberman, et al., 2002). Implicit memories are based on lived experience. Situations are saved as multimodal sensory patterns consisting of everything we perceive, even nonconsciously, in a specific situation – what we hear, feel, see and smell. Also the feeling of failure or success will be saved as part of the whole pattern, a so called somatic marker (Damasio, 1994). Logan suggested that *'subjects store and retrieve representations of each individual encounter with a stimulus'* (Logan, 1988, p 501). Each representation is stored in the implicit memory system as a unique holistic pattern (Björklund, 2008).

Using holistic pattern recognition as a way to solve problems or identify phenomena has been described as non-analytic reasoning (Norman, et al., 2007). This strategy is based on similarity to previously encountered exemplars. Between experts in biology, especially ornithologists, this way of characterizing objects has been known for almost a century. Gestalt recognition was often described as *'knowing'* an aircraft or bird, or recognizing its particular *'sit'* or *'character'* terms synonymous with T.A. Coward's *'jizz'* of bird species: immediate, unconscious identification, without the need for analysis. *"Jizz may be applied to or possessed by any animate and some inanimate objects, yet we cannot clearly define it. A single character may supply it, or it may be the combination of many... Jizz, of course, is not confined to birds. The small mammal and the plant alike have jizz"* (Coward, 1922). A Dictionary of Birds by Campbell and Lack (1985) defines jizz as: *'A combination of characteristics which identify a living creature in the field, but which may not be distinguished individually'*. The official 1946 UK War Office training manual on how to recognize airplanes states that: *"to the sportsman or country dweller a bird is recognized by its general appearance and method of flight - not by details of the exact shape of various parts of its body. Similarly, an aircraft is recognized by its general appearance and 'sit' in the air, not by precise constructional details"* (Anonimus, 1946). We infer that this holistic way of identifying objects, natural or artificial is using implicit memory patterns.

As we re-experience a similar situation, the implicit memory system will make an unconscious pattern recognition to help us feel and act in the same way as we did the last time (Lieberman, 2000). Automatic action, initiated by pattern matching, makes the implicit memory system rapid (Lieberman, et al., 2002). Pattern matching function does not use Working Memory which implies that the implicit memory system does not suffer from cognitive load (Evans, 2008). It will be able to handle complex situations. When a situation, which has been earlier encountered and stored in the implicit memory system, is re-lived the pattern matching function will direct the conscious vision to a detail which is of importance in a specific situation (Chun & Jiang, 1999; Maljkovic & Nakayama, 2000). In this way we will be able to attend to the most relevant part of a

complicated scene. When a craftsman moves his hand to manipulate an object, he use a special cortical system providing “vision for action” (Milner & Goodale, 2008). This system is anatomically separated from “vision for perception”, which is active when people for example look at an object trying to identify it. These two systems have been described as unconscious and conscious, respectively. We propose that these cortical systems are to be identified as the implicit and the explicit memory systems respectively. “Vision for action” is a system in which the periphery is relatively well represented (Milner & Goodale, 2008). This wide-angle view has been shown to facilitate implicit object recognition (Boucart, Naili, Desprez, Defoort-Dhellemmes, & Fabre-Thorpe, 2010).

Trying to understand the behaviour of the characteristics of expertise, we will begin by taking a look at the novice. As a novice teacher (for example a student teacher in his/her first field experience period) steps into the classroom, he or she does not have experience from the classroom as a teacher. Thereby, it is not likely that any implicit memories are available to the novice. This means that the explicit memory system is the only system available to the novice. To manage the classroom situation the novice is dependent on rules and conscious, analytical thinking. Since the novice does not know which details are important in the specific situation, he or she will have difficulties sorting out what to attend to. This will lead to the novice making decisions that are less accurate and more time-consuming than would the expert (Norman, et al., 2007). Contrary to the novice, the expert will have access to holistic pattern recognition (Dreyfus, 2004; Norman, et al., 2007). The implicit wide-angle vision takes in the whole picture of the classroom at every single moment and through pattern matching the experts’ conscious attention will be guided to where it is needed. This will lead to less risk of cognitive load, since no analytical processes are involved. Decisions will be made on the basis of lived experience and will be rapid and appropriate. Much of the action and decisions are hidden, intuitive to expert teacher, and not possible to verbalize; the knowledge is *tacit* (Polanyi, 1967).

Use of the Model in an Empirical Study

In a recent study Björklund and Stolpe followed two expert teachers with their students in a complex environment, in this case, nature during an excursion (2010). The expert teachers identified natural objects during an ecology field excursion using holistic pattern recognition but taught this skill using features and details. They showed automatic behaviour in attending to birds and other animals, finding small and large objects of learning, adapting their teaching to the student’s different modes. The episodes could be analysed and understood using the dual systems theory and especially tacit knowledge, as the ability to find a safe path through a peat bog, could be connected to somatic patterns stored in the implicit memory system. We would claim that this holistic pattern recognition is used by teachers in all situations in which they have lots of experience. The ability to categorize natural scenes through global properties and not by objects and parts has been described by Greene and Oliva (2009). They also show that this categorization is rapid (see also Griffiths, 2010; Thorpe, Fize, & Marlotet al, 1996) which indicates that the implicit memory system is involved in the process (Chun & Jiang, 1999). Taken together, these results suggest that the holistic pattern recognition, which is shown by the teachers in the present study, is a result of implicit learning. We claim that when the teacher walks on the peat bog knowing exactly where

to put his feet without getting wet, he acts in accordance with the experience of sinking or not that has been stored in his implicit memory system. Non-consciously he recognizes the dangerous as well as the safe paths and acts automatically. He recognizes the context and acts intuitively in accordance to his implicit memories. In the interview it becomes clear that this is a skill which he cannot explain nor describe, “it is trial and error”. He has knowledge that he uses but that he is not aware of; in Polanyi’s words: “you can know more than you can tell” (p. 4). The knowledge is tacit, stored in the implicit memory system.

To manage the classroom is, for the expert teacher, in many terms an automatic action (Ainley & Luntley, 2007). We will shed light on this process in suggesting that this behaviour is automatic since it is based on implicit knowledge which in turn is based on lots of experience. The teachers in our study have many years of experience from being out in nature and have thereby formed implicit knowledge of different species, lakes and other phenomena found in nature. However, it is not enough just being out there. One key to the formation of implicit knowledge is *deliberate practice* in which well defined tasks, informative feedback, repetition, self-reflection, motivation and endurance are important factors (Moulaert, et al, 2004).

This implies that when it comes to teaching, deliberate practice is a way to collect exemplars of teaching situations; when teaching works out well and when it fails, when students are interested and when they are not and when they understand or not. All these situations are stored as exemplars of particular situations. We will feel familiarity as a new upcoming situation is matched against one of the stored exemplars of the situation (Norman, et al., 2007). Since implicit memories sometimes are marked with an earlier outcome, a somatic marker (Damasio, 1994), an automatic and rapid response is possible. Thereby we propose that the attention-dependent knowledge, introduced by Ainley and Luntley, is identical to implicit knowledge. This knowledge helps guide the attention of the expert teacher, a skill which is also described in earlier research (Berliner, 2001; Dreyfus & Dreyfus, 1986; Johansson & Kroksmark, 2004; Kerrins & Cushing, 2000; Krull, , 2007; Sabers, et al., 1991).

Conclusions and implications for teaching

The teachers were not aware of their two complementary memory systems and were using conscious, declarative strategies to teach. However, in being out in the nature, the teachers offered first hand sensory experiences of the object of learning. From research on the formation of implicit memories, it is thereby possible to predict that the students created implicit memories which facilitated the development of a holistic pattern recognition skill.

We claim that by using the modified dual memory system model we are able to explain the observational skills shown by experts. It is a pattern matching mechanism which is stored and processed in the implicit memory system. The somatic marker facilitates non-conscious decision-making and judgment explaining why these things are tacit and so hard to verbalize for an expert. The pattern matching mechanism also controls our conscious attention and directs our visual focus. This shows the great importance of an experienced teacher to tell the student where to look. But it will also emphasize the importance of a direct encounter with objects, tools, materials and concrete examples. The implicit patterns will initiate our conscious, explicit memories of methods,

algorithms and solutions to a problem. This could be the answer to Ryles question of what starts our thinking process (1949). The outcome of these mechanisms shows up as automatic behaviour and forward reasoning in problem solving which is typical for the expert. We would argue that the teachers must give students firsthand sensory experience which is a prerequisite for the formation of implicit memories. Thereby holistic pattern recognition is made possible and an ability to discern a system, to see the wood for all the trees.

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