THE INTUITIVE PRACTITIONER:
Cognitive aspects on the development of Expertise

INTRODUCTION
Patricia Benner who published the first study following the Dreyfus model describes an expert nurse in the following way: “If you take a moment to evaluate your practice, you’ll see that you can look at your patients and notice the smallest changes in them. When something is wrong, you can almost feel it, even if it doesn’t register on a monitor. You observed subtleties—a slight variation in breathing pattern or an alteration in color. From past clinical experiences, you know when there’s about to be a major change in a patient’s status, and combining experience with scientific knowledge, you instinctively prepare for treating that challenge. You are an expert nurse. Your responses are shaped by a watchful reading of the patient without recourse to conscious deliberation. Your performance is fluid, almost seamless. When you recall an event, you focus on informed action, rather than organization, priority setting, and task completion”.(Benner, 1997)

In recent years the interest in expertise and proficiency has been raising, in educational research, knowledge management as well as in cognitive science. John Stevenson defines expertise as the ability to do something well - Better than others just starting out on the undertaking (Stevenson, 2003), He proposes several interesting research questions; What do we mean by doing something well? What enables an individual to do something well? Why does this capacity improve with practice? Is this capacity confined to a specific field, or is it general? Can the capacity be learned, and how? Where is it located?

The quest of eliciting knowledge from experts has eluded science since the beginning of the development of artificial intelligence in the 1960s'. The database of an Expert System has to be loaded with knowledge from human experts and these experts seem to be unwilling or incapable to tell about their rules and methods. When we are using standard interview techniques we are probing the conscious, rational and logic mind of the interviewee. The informant may want to please us and tell us what is appropriate, logic and sound. Our data will be full of general rules and standard procedures and not the individuals’ own subjective way of coping with problems. The experts know how or procedural knowledge is hidden even for him or her self, it is tacit. We know more than we can tell. (Polanyi, 1966)

This knowledge is apprehended in an implicit way often outside our own awareness. It is often used in an automatic way and is therefore difficult to elicit by introspection.(Nisbett & Wilson, 1977) In modern psychology Dual or multiple cognitive systems theories have been making progress during the last three decades and they have given us new ways of understanding tacit knowledge, expertise, intuition, insight and automation. (Cronin, 2004; Epstein, Lipson, Holstein, & Huh, 1992; Ericsson & Charness, 1997; Lieberman, 2000; Nightingale, 1998; Arthur S. Reber, 1989; Sloman, 1996; Sun, Slusarz, & Terry, 2005) The purpose of this paper is to shed some light on experts and expertise using results from different domains of Cognitive Science and discuss the implications for research and educational design.

METHOD
Cognitive science consists of many different domains of research; psychology, neuropsychology, neuropsychology, neuromedicine and many others. Modern science is drilling deep holes to find new knowledge and the adapted method of specialisation and reduction has made its different domains separated from each other. This paper is an “Integrative research review”, trying to show new aspects of experience based learning and the development of expertise. “Integrative reviews summarize past research by drawing overall conclusions from many separate studies that are believed to present the state of knowledge concerning the relation(s) of interest and to highlight important issues that research has left unsolved. From the reader’s viewpoint, an integrative research review is intended to “replace those earlier papers that have been lost from sight behind the research front and to direct future research so that it yields a maximum amount of new information.”(Backman, 1998; Cooper, 1984; Light & Pillemer, 1984) Its reliability and validity can only be assessed by the extent to which the devised model can “explain” the phenomena it is addressing. The complexity of the human brain makes it essential to use appropriate tools in the design of the model. Modern technology, dealing with complex systems, has developed intellectual tools for this purpose.(L. Björklund & Klasander, 2004) The first cognitive constraint to address is our brain’s limited resource of working memory, in which all conscious cognitive processing occurs. The working memory can handle only a very limited number, possibly no more than two or...
three interacting elements. (Paas, 2003) Therefore the complex has to be described in an appropriate scale of
detail with just a small number of separate units. A second aspect of a systems approach is the importance of
functional descriptions.(Lars Björklund, 2006) Functional modelling provides an abstract, yet direct, method for
understanding and representing an overall product or artefacts function.” (Hirtz, 2002) In Technology a
difference is made between the structure and function of an artifact and this is also recognized in Science,
especially in the biosciences.(Hmelo-Silver, 2004) Three system levels are identified in this paper, the individual
expert who’s abilities and behavior are to be described in functional terms, an intermediate psychological level
where the behaviors of an expert are studied with hypothetical functional memory-structures, and on the most
basal level neurophysiological structures described in their functional properties and behavior. The top level has
been studied for a century, the medial level for half a century and the last is a contemporary highly evolving area
of research. The author is trying to shed some light on the abilities and behavior of an expert and propose and
endorse directions for research.

THE SYSTEM ,RESULT OF A LITERATURE REVIEW

Top level: Experts and expertise

The nature of expertise have been studied extensively in the last 100 years, either by the inspection of the truly
exceptional individuals chosen by their well established and recognized discoveries, works, results and
innovations; scientists, innovators, composers, chess players writers etc. or by studying relative expertise and the
development of higher level of abilities and skills. (Chi, 2006) The earliest literature was focusing on exceptional
individuals; composers, chess players, athletes, writers, scientists, innovators and others and was trying to find
intrinsic causes and explanations to the outstanding expertise of an individual. Co variation with talent, genetics,
general IQ was searched for but was found very weak. A common result of these studies was that the expert had
practised more and had acquired more knowledge in a specific domain and that this knowledge was structured,
organized and better represented.(Chi, 2006) Contemporary research takes a more relative view of expertise,
studying what differentiates an expert from a novice in a domain of practise. The level of expertise is not
absolutely defined but viewed in relations to other individuals on a lower level of proficiency. The causal reason
for expertise used to be the idea of a higher, faster, more abstract general thinking ability. Today this view is
changing; “Thinking at its most effective depends on specific, context-bound skills and units of knowledge that
have little application to other domains. To the extent that transfer does take place, it is highly specific and must
be cued, primed and guided; it seldom occurs spontaneously. The case for generalizable, context-independent
skills and strategies that can be trained in one context and transferred to other domains has proven to be more a
matter of wishful thinking than hard empirical evidence”.(Perkins & Salomon, 1989)

An interesting strand of research emanates from Herbert and Stuart Dreyfus and their description of human
abilities and the development from novice to expert in five stages.(H. L. Dreyfus & Dreyfus, 1986) The
behaviour and abilities of the individual are according to their model developing during deliberate practice,
caused primarily by two factors; an influx of contextual and situational data and a personal responsibility for the
outcome of decisions and actions. Their model have been used in many areas of expert research;
teaching,(Berliner, 1986) nursing, (Benner, 1984), managing. (Stefl, 2003) and others.

The two discourses mentioned above have defined their stages of proficiency in different ways and care must be
taken not to mix them. Hoffman uses the following descriptions of different levels of expertise: Naïve, Novice,
Initiate, Apprentice, Journeyman, Expert and Master.(Hoffman, 1998) where Dreyfus the following: Novice,
Advanced beginner, Competent, Proficient and Expert.

Intermediate level: Psychologists’ view on knowledge, memory and learning

Ryle (1949) distinguished between knowing how and knowing that, and Bruner (1969) contrasted
memory without record and memory with record. In the 1970s a similar distinction was discussed in the
artificial intelligence literature as procedural and declarative knowledge. The study of implicit memory emerged
from the decade of the 1980s at the forefront of memory research,(Schacter, 1992) Implicit memory is an
unintentional nonconscious form of retention that can be contrasted with explicit memory, which involves
conscious recollection of previous experiences. Brain damaged amnesic patients with severe impairments of
explicit memory can exhibit intact implicit memory. In experimental psychology several different models for
learning and behaviour have been proposed. Reber used the concept of implicit learning to be able to explain
of a multitude of experimental results during the last decades of the 20th century. Logan proposed a model of an
implicit memory based on pattern recognition, the “instance theory”. (Logan, 1988, 2002) Several models of similar function have been proposed but the task of modelling the black box of the brain has been hard using only external tools.

**Basic level: Neurophysiology**

New brain imaging tools as functional magnetic resonance imaging (fMRI) and PET made the Black box transparent. It is now widely accepted that many brain systems are capable of learning and storing information. Some of these function explicitly and give rise to our conscious declarable memories, while others function implicitly and store memories that are accessed and used automatically, or unconsciously. Most systems are using memory and its underlying neuronal plasticity to allow them to perform their function (emotional control, sensory processing, motor regulation, etc.) more effectively.(Phelps & LeDoux, 2005) Contemporary models of the brain use a hierarchy of several memory systems, first divided into declarative and nondeclarative memory systems. Behaviour and sub functions of different neuro structures are explored and published by the day.

![Figure 1 A taxonomy of long-term memory system.](Squire, 2004)

The memory systems of the brain operates in parallel to support behaviour, sometimes competitive, sometimes supportive. The various memory systems can be distinguished in terms of the different kinds of information they process and the principles by which they operate. In the case of declarative memory, an important principle is the ability to detect and encode what is unique about a single event, which by definition occurs at a particular time and place. In the case of nondeclarative memory, an important principle is the ability to gradually extract the common elements from a series of separate events.(Squire, 2004) The hippocampus is crucial for conscious, explicit memory,(Degonda et al., 2005) and components in the caudoputamen and amygdala are dedicated to the processing of reward, reward contingencies, or positive affective states. For example, dopaminergic transmission in the caudoputamen, which is implicated in a range of positive affective and reward processes, may play a role in safety conditioning.(Rogan, Leon, Perez, & Kandel, 2005) The caudate nucleus supports incremental learning of stimulus-response associations, or more specifically, the acquisition of place-appropriate responses leading to habitual. In contrast, the hippocampus is central to the rapid acquisition of declarative knowledge about the environment, generating a so-called cognitive map.(Voermans et al., 2004) Studies have found a series of subcortical visual structures that plausibly comprise a subcortical pathway terminating in the amygdala. This pathway, proceeding from the retina to the superior colliculus (SC) to posterior nuclei of the thalamus and on to the amygdala, bypasses detailed cortical processing and is thought to provide the amygdala with lower-resolution but more rapidly processed visual input (LeDoux, 1996). Some accounts emphasize the bias of this system for stimuli that are informative about potential dangers.(Pasley, Mayes, & Schultz, 2004) The basolateral amygdala modulates the cognitive and habit memory processes mediated by the hippocampus and caudate nucleus, respectively and may therefore “amplify” cognitive processes and direct attention to matched patterns. it has the capacity to process higher-order knowledge.
Automation
Experts often develop automaticity for the repetitive operations that are needed to accomplish their goals. They show high accuracy in reaching appropriate solutions, even under time constraint. (Berliner, 1994b; Chi, 2006; Groot, 1965; Sternberg, 1998)

- A study in wayfinding may give a clue to the structure behind this behaviour: “The first, place learning, is dependent on the hippocampus (explicit memory) and permits the formation of a cognitive map that is flexible enough to facilitate navigation via a novel route. The second, response learning, is dependent on the caudate nucleus and supports an action based representation that is inflexible (only supporting navigation via the same well-learned route) but which may have the advantage of mediating fast, automatic responses. (Hartley, Maguire, Spiers, & Burgess, 2003)

Contextual and situated knowledge
Expertise is specific to a domain, developed over hundreds and thousands of hours, and it continues to develop. Experts excel mainly in their own domain and in particular contexts. (Berliner, 1994a; Chi, 2006; Sternberg, 1998) - The dual system aligned above shows a similar behaviour, Initially hippocampal learning, rules, are used to control action but after a long time of repetition caudate nucleus takes control, reacting on primed stimuli. The striatum is not only involved in the implicit automatization of serial information through prefrontal cortex-caudate nucleus networks, but it also plays a significant role for the selection of the most appropriate responses in the context created by both the current and previous stimuli, thus contributing to better efficiency and faster response. (Peigneux et al., 2000) The evaluative function of Amygdala and Caudet-putamen will also gain from experience and make the expert better in recognizing outcome of perceived contextual patterns

Pattern recognition
Experts recognize meaningful patterns faster than novices. Experts impose meaning on ambiguous stimuli. Experts make substantially more inferences from and assumptions about the information presented to them than do novices. Their inferences, assumptions, and predictions allow them, like hockey pro Gretsky, to "go where the puck is going to be." Expert can detect and see features that novices cannot. They can see patterns and cue informations. (Benner, 1984; Berliner, 1994b; Cellier, Eyrolle, & Mariné, 1997; Chi, 2006; S. E. Dreyfus, 2004; Sternberg, 1998)

- As above!

Metacognition
Experts are more likely to be able to plan their solutions at a descriptive meta-level. Experts exhibit a forward inference rather than a backward inference order of problem solving. They predict accurately the difficulty of solving particular test problems and then monitor carefully their own problem-solving strategies and processes. (Dhillon, 1998; Priest, 1992; Sternberg, 1998)

- Automatization frees cognitive resources for planning and overview

Flexibility
Experts are flexible opportunistic planners, they develop self-regulatory processes and are quick to change tracks whereas inexperienced novices exhibits a functional fixedness. The moment of action and the parameters of the action seem to be defined in the course of the interaction between the expert and the task. The experts solves problems in a non reductive manner, describing order as an emergent property of decentralized interactions in a system, and considers nonlinearity and random factors. (Berliner, 1986; Cara & Lagrange, 1999; Jacobson, 2001)

- When automatization is seen as micro-responses to events and patterns the expert who has a large number of patterns and responses will be able to handle many different situations in a flexible way and is not bound to a fixed and rigid plan.

Dwelling
Experts are usually more constrained by the task requirements and the social constraints of the situation than are novices. They are more evaluative than are novices and less detached. An expert takes personal responsibility and is involved in the outcome of his or her performance. (Berliner, 1994a; S. E. Dreyfus, 2004)

Amygdala is used for emotionally important patterns, if the feedback is missing or is weak, no patterns will be recorded. (Smith, Stephan, Rugg, & Dolan, 2006)
Tacit knowledge
It is difficult for experts to describe exactly how they do what they do, especially with respect to their use of judgment, experience, and intuition. This is called the knowledge-acquisition problem. (S. E. Dreyfus, 2004) Not only in artistic judgement but in all their ordinary judgements of the qualities of things, they recognise and describe deviations from a norm very much more clearly than they can describe the norm itself. (Schon, 1987)
- Most of the structures involved in expert behavior are separate from declarative memory structures and can not be introspected, any verbal description is a construction made from other explicit data.

Problem solving
Experts are working forward from given information to find unknowns in the problems. This is called forward reasoning in contrast to the Novices method of “Trial and Error” or backward reasoning.
- Problem solving incorporates a moment of pattern matching between the functional description of the virtual artefact and the behaviour of the substructures of the real anticipated artefact. The larger the receptory of old problems the more often will a direct solution happen.

Development
Development of expertise is not linear. Non-monotonocities and plateaus occur, indicating shifts in understanding and stabilization of automaticity. Time to reach expertise varies with professions between 5 to 10 years.
- Time to build patterns and appropriate actions for the nondeclarative systems is long!

Intuition
Both the size and the organization of knowledge bases may explain how experienced teachers are able to function on automatic pilot, leaving working memory free to monitor classroom activity. Much of the interaction between teachers and students is automatic, over learned patterns of behaviour that teachers could invoke and perform without conscious effort. Experienced teachers appeared to have organized their knowledge of students and classrooms in particularly effective patterns (schemata) that could be retrieved unconsciously from long-term memory via classroom cues. They used these patterns to interpret classroom events and to decide which routines to use. (Johansson & Kroksmark, 2004; Kagan, 1988; Kroksmark, 1997)
- In a study by Kahn the results supported a role of the amygdale in choice behavior, both in the appraisal of inherent value of choice and the signalling of prospective negative outcomes. (Kahn et al., 2002) The emotion sensed when a situation is assessed by amygdala may be what we refer to as intuition and gut-feeling.

Knowledge
Experts represent problems in qualitatively different ways than do novices. Knowledge is structured better, deeper and richer. (Sternberg, 1998)
- The use of a large number of instances/ patterns to assess the situation and to take action may be interpreted as if the knowledge base has different and higher qualities.

CONCLUSION
Several new results from brain imaging studies and from neuropsychology gives reason to believe that experts utilize nondeclarative, implicit memories to perform better. It delivers new ways of understanding tacit knowledge, intuition and holistic perception. Research on experts and expertise using a model of several parallel memory structures could be prosperous.

REFERENCES
Education for a Diverse World (pp. 123-134). Lublin: Maria Curie-Skodowska University Press.


**AFFILIATIONS**

Lars Björklund  
PhD-student at Swedish National Graduate School in Science and Technology Education Research and lecturer at Department of Physics, Chemistry and Biology  
University of Linköping  
Sweden