

# The forming and assessment of creative skills, from a neurocognitive point of view

## Introduction

Most subjects in modern school have an element of creative work. It is a goal of many curricula, to enhance skill and to foster the ability to design and innovate. In Art and Craft Education this goal plays a major role but it is important in other subjects as well. During the last two decades a new comprehensive subject, "Technology" or "Design and Technology", has been introduced in many countries. In these curricula creative design is a core activity.

*But, what is creativity? Can it be defined in words? Can it be evaluated?  
Does any development occur? Can creativity really be taught?*

These questions are important to address.

In the curriculum for the Swedish subject "Teknik" knowledge on these items seems to be taken for granted. The description of the design process in this document is vague:

*A practical and inquiry based work will illustrate the design process; Defining the problem, forming a hypothesis, planning, prototyping, testing and modification.*(Education, 2000)

This is a criticized, simplified, prescriptive and linear description of the design process. Studies of professional designers in action shows that the processes are not linear, they are reiterative and very individual.(Mawson, 2003; Middleton, 2005; Petroski, 1996; Williams, 2000)

Traditionally, assessing the finished product, the constructed artefact, the painting, the model of a bridge has been the way to assess creative work. This will grade the students but will not give any useful clues or feedback to the student as it is focusing on the end result and ignores the process of making. To be able to assess process we need to know more about the strategies, the skills, the abilities, and the habits of mind of experts in the designing task. What behaviour is to be promoted and which signs of progression are to be identified? At first it seems as if every design task is unique but studies of experts in different areas of practice show that there are common properties and behaviour to be seen.

In a large study about creative development in Art education professor Lars Lindström tried to find criteria's or descriptions of general abilities used by teachers to assess creative work. (Lars Lindström, Ulriksson, & Elsner, 1999) After a thorough literature survey, several experts, teachers but also artists and craftsmen, were interviewed with the Repertory Grid and other techniques. Elements in the RGT-interview process were artefacts of fine metal craft.

With the help of elicited constructs, laddering and deep interviews of the experts a list of important factors/criteria for the development of creativity was devised:

**Product criteria:**

1. *Visibility of the intention/ Goal fulfilment*
2. *Colour, form and composition/ Visual qualities*
3. *Craftsmanship/ Technical skill*

**Process criteria:**

4. *Investigative work/ Persistence in the pursuit*
5. *Inventiveness/ Imagination and risk-taking*
6. *Ability to use models/ being able to learn from others*
7. *Capacity for self-assessment/ knowing one's strengths/weaknesses*

**Others:**

8. *Overall judgement*

Every criteria was described in four steps notifying a developmental, progressional change from the behaviour of a novice to that of an expert. The levels were described in a narrative way, a rubric, to make it possible for a teacher to recognise the behaviour of a particular student. The following rubrics were used for scoring 3. Craftsmanship:

1. *The pictures show little or no ability to use materials and techniques.*
2. *The pictures suggest a certain ability to use materials and techniques, but there are serious deficiencies in the execution.*
3. *The pictures show an ability to use materials and techniques to achieve the desired visual effects, but this is applied in a rather stereotyped way.*
4. *The pictures show a good and flexible mastery of materials and techniques and are consistently of high technical quality.*

The following rubrics were used for scoring 7. Capacity for self-assessment:

1. *The student cannot point out the strengths and weaknesses of her own work or distinguish between works that are successful and those that are less successful. She has no opinions about her fellow students' pictures.*
2. *With some assistance, the student can point out the strengths and weaknesses of her own work and distinguish between works that are successful and those that are less successful. Opinions about her fellow students' pictures are confined to simple value judgements (good/bad, like/don't like).*
3. *The student is generally able to see merits and shortcomings in her work and can select sketches, drafts, and works which illuminate her own development. She can pass varied judgements on her fellow students' pictures.*
4. *The student can clearly see merits and shortcomings in her work and can select sketches, drafts, and works which illuminate her own development. She can also give reasons for her judgements and explain why things turned out as they did. She can pass varied judgements on her fellow students' pictures and is able to give constructive criticism.*

“There is an obvious difference between the criteria of excellence that were generated by this and following studies and those checklists that are often found in textbooks. The latter list components that should be present in a product or performance, while the interviewees in this study rather tried to define a set of more general dispositions or key competencies. The typical textbook items are, at best, indicators of such “habits of mind”. The interviewees’ process criteria, in particular, add up to a culture of learning rather than a list of specific skills.” (Lars Lindström, 2002, 2007)

Lindström and his colleagues found high agreement between class teachers and co-assessors in ratings of both the students' visual results (product criteria) and their approach to work (process criteria) i.e. reliability was high. In almost 3,100 comparisons between class teachers and the coassessors from another school, they found a 78 per cent agreement (= 2 steps on a twelve-grade scale). (Lars Lindström et al., 1999)

## Experts and expertise

Interest in experts and expertise has been great and the matter has been studied intensely during the past century. Two main streams appear in literature, one being the study of exceptionally skilled and recognised individuals who have been selected on account of their remarkable discoveries, works, results or inventions. The other stream contains studies on how expertise is developed over time and increasing experience.

The earliest studies tried to find causes of and explanations to why famous composers, sportsmen, chess masters, authors, scientists and other experts had been successful. There were attempts at linking expertise to talent, heredity and intelligence but very little covariance was found between those factors. What different groups of experts have in common, though, was that they had practised their work for a long time and had great knowledge within their own field. This knowledge also seemed to be structured, better organized and represented. (Chi 2006).

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)

Contemporary research takes a more relative view of expertise, studying what differentiates an expert from a novice in a specific domain of practise. The level of expertise is not absolutely defined but viewed in relation to other individuals on a lower level of proficiency. 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?*

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 *Novice, Advanced Beginner, Competent, Proficient and in the final stage the intuitive Expert*. (H. L. Dreyfus & Dreyfus, 1986). The behaviour and abilities of the individual are according to their model developed 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. The rule-following novice will in time be more contextually aware and

use more experienced-based intuitive knowledge. Their model has been used in many areas of expert research: teaching, (Berliner, 1986) nursing, (Benner, 1984), managing (Stefl, 2003) and several others. When you study novices becoming experts you will recognize a development and often a change in behaviour during problem solving activities. The experts seem to be able to concentrate on the salient features of the task, they act fast and proficient and they share some important habits of mind controlling their design process. (Middleton, 2002) Another characteristic of an expert is the inability to verbalize the know how, it's tacit. The quest of eliciting knowledge from experts has eluded science since the beginning of the development of artificial intelligence in the sixties. The database of an Expert Systems had to be filled with knowledge from human experts and these experts seemed to be unwilling to tell about their secrets and methods. When you are using standard interview techniques you are probing the conscious, rational and logic mind of the interviewee. The informant may want to please you and tell you what is appropriate, logic and sound. Your data will be full of general rules and standard procedures and not the individuals' own subjective way of coping with problems. His know how or procedural knowledge is hidden even for him, it is tacit.

*We know more than we can tell. (Polanyi, 1966)*

This knowledge is apprehended unconsciously in an implicit way often outside our own awareness. It is also used in an automatic way and is therefore difficult to elicit by introspection and methods like stimulated recall. "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". (Schon, 1987) This is because our ability to recognize patterns and familiarity in an area of our own expertise is strong. We may not always know why but intuitively we feel what is good, bad, beautiful, sloppy, clear, original etc. The research field of expertise, design and creativity is full of unanswered questions and strange phenomena but new findings in several cognitive sciences have opened up new paths of understanding of which this paper will mention a few.

## Method

Cognitive science consists of many different domains of research: psychology, neurophysiology, neuropsychology, neuromedicine and 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 compiled from a PhD thesis an "Integrative research review", trying to find and show new aspects of creativity and the development of design expertise. (Björklund, 2005, 2007, 2008a, 2008b) "*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.

## Result

In Cognitive Science Dual Cognitive systems theories has matured during the last 20 years and has given us new ways of understanding tacit knowledge, expertise, intuition, insight and automation.

Modern research in psychology, supported by seminal findings in brain research has given us a new model of mankind's learning system that may explain many of the anomalies, and peculiarities in the way we perceive and act in the world. A dual-system model of memory and learning has been refined during the late 20th century and gives evidence for us to believe in two different ways of viewing, analysing, understanding and acting in the world. (Cronin, 2004; Epstein, Pacini, Denes-Raj, & Heier, 1996; Ericsson & Charness, 1997; Lieberman, 2000; Nightingale, 1998; Arthur S. Reber, 1989; Sloman, 1996; Squire, 2004; Sun, Slusarz, & Terry, 2005; Zeithamova & Maddox, 2006)

The Cartesian view of a split between the body and a separated single mind has changed towards a model where a conscious, explicit and declarative memory system lives alongside an unconscious, implicit and tacit system. The behaviour and function of this second, implicit system, have been studied by experimental psychologists, and with new data from brain-imaging research a radically new understanding of knowledge and knowing is at hand. This will raise the value of experience and complement the idea of rational, scientific and evidence-based knowledge.

### Psychological studies of unconscious, implicit learning

Psychologists have been performing a multitude of experiments during the last part of the 20<sup>th</sup> century focusing on memory and learning processes, but models of human reasoning and behaviour are even older. Ryle distinguished between knowing how and knowing that (Ryle, 1949). Bruner (1969) contrasted memory without record and memory with record. In the 1970s a similar distinction was discussed in artificial-intelligence literature between 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, a fact has been recognised by practising doctors for a long time. (Damasio, 1996). 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 unconscious learning of abstract grammar rules. (A.S. Reber, 1967) The idea of a dual cognitive system grew out 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 similar models using dissociation between explicit and implicit memories have been proposed but the task of modelling the black box of the brain has been difficult using only external tools. Implicit learning is now seen as non-episodic learning of complex information in an incidental manner, without awareness of what has been learned. It associates environmental stimuli that are relevant for behaviour. (Dienes & Fahey, 1998; Frensch & Runger, 2003; Seger, 1994)

### Neurophysiological studies

Gauges like "functional magnetic-resonance imaging", fMRI, and "positron emission tomography, PET, have given scientists new possibilities to study brain activity. It is possible to follow how the different parts of the brain are supplied with blood and in that way receive

indications as to what parts are active. By conducting traditional psychological experiments while monitoring brain activity a great deal of knowledge and understanding has been created on the topic of man's learning, memory and behaviour. It has been shown that many functional systems in the brain can adapt to the environment and change their function; they learn. Some of them are explicit and create declarative, conscious memories whereas others are implicit and create memories that are used automatically, outside of conscious control. Earlier known systems to control movement, sensory information and feelings have turned out to have learning functions; their neurons are "plastic" and can adapt in order to achieve better efficiency. (Phelps & LeDoux, 2005)

A model built on neurophysiologic results of the learning system of the brain is shown in Figure 1

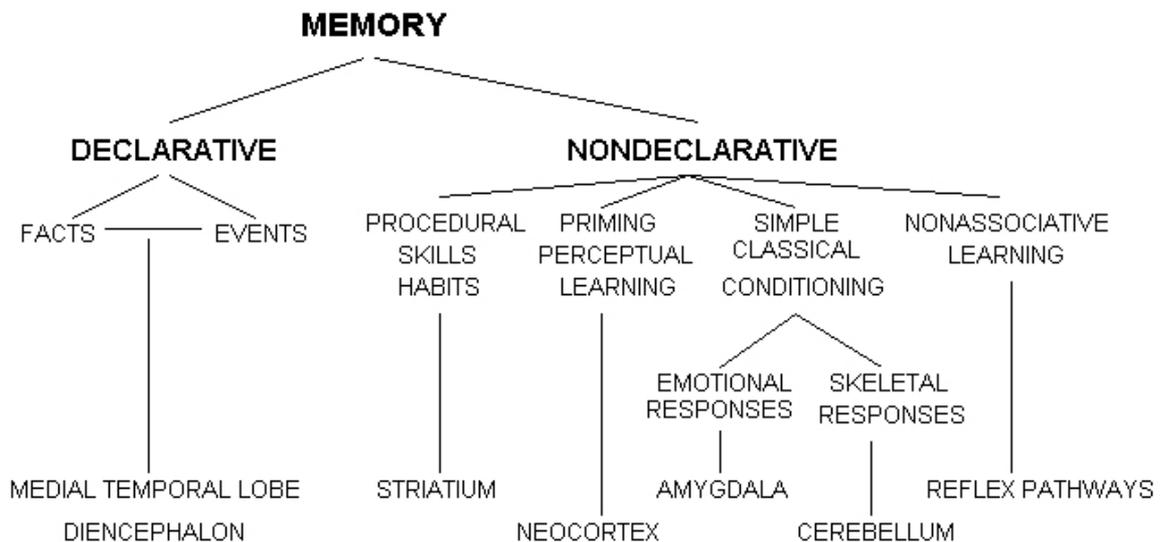


Figure 1 Long-time memories in the brain (Squire 2004)

These systems work parallel to each other, sometimes supportive, sometimes competitive. Two main groups of memory systems are separated by the type of information they contain and how it is used. In the declarative memories what is saved is unique about a specific event, what happened but also time and place are important. In the non-declarative memories what is saved is common for a number of separate events, a process that goes on gradually but make it possible to adapt to the environment in the best way.(Squire, 2004)

The hippocampus is crucial for conscious, explicit memory (Degonda et al., 2005) and components in the striatum/ caudoputamen and amygdala have to do with the processing of reward, reward contingencies, or positive affective states.

The implicit learning system has a strong impact on the development of skills and expertise, and it brings a new understanding of tacit knowledge, intuition and holistic-pattern recognition. What Polanyi refers to as Tacit knowing is implicit learning, and this explains why *we can know more than we can tell*. The Dreyfus model of novice-expert development can be explained as a slow change of utilisation of the two memory systems. The rule-following novice uses explicit memories and the expert has access to a large library of implicit memories. The function of the implicit memory is to let the individual recognize habitual, dangerous or rewarding situations. Patterns of raw sensory data representating the

context are *stored* in long time memories. Structures as the basal ganglia, the amygdala and striatum and possibly the cerebellum have been identified as areas active in this learning process (Cincotta & Seger, 2007; Ilg et al., 2007; Nomura et al., 2007; Seger, 2006).

Old philosophical aspects of knowledge known as “*techne*” and “*phronesis*” are given neurobiological causes and explanations. The implicit system and the secondary implicit vision, along the dorsal the low route, will enhance an experts ability to observe, assess, characterise and take action. Sometimes in an automatic, intuitive way.

### Implications for creative work and problem solving

Wallas (1949) proposed a four-stage process of creative thought (Preparation, Incubation, Illumination and Verification). He proposed that during these four stages the thought process would move from conscious thought patterns to unconscious, and then back again to conscious patterns. Low (2006) describes these stages in his thesis:

- *Preparation - This stage involves an intense effort to solve the problem: the gathering of all data possible, problem identification and problem definition, and if a solution is not found the problem is abandoned.*
- *Incubation - During this stage the problem solver’s conscious thought processes are turned to matters other than the problem, while subconscious thought processes work on the solving of the problem. When a solution is arrived at the mind delivers the proposed solution from the subconscious to the conscious.*
- *Illumination - This is the “aha” or sudden insight into the possible cause of or solution to a problem on which the researcher may have been working. In this model the subconscious mind “delivers” the solution or idea to the conscious mind.*
- *Verification - During this stage, the details of the solution found are checked against the reality and found to be either a valid solution to the problem or another way of not solving the task at hand.*

In this four-stage model of creative thought, the stage of preparation activates patterns stored in implicit memories. Since these are memories of specific instances (Nosofsky & Zaki, 2002) a very close likeness must be at hand for recognition to happen. A huge library of experience patterns and elaborate exploration will facilitate the match (R. Reber, Ruch-Monachon, & Perrig, 2006). This is also what is promoted in the *variation theory* (Marton, 2006). In the case of an impasse this unconscious pattern matching may continue in the incubation stage, which has been demonstrated recently giving birth to “A Theory of Unconscious Thought” (Cronin, 2004; Dijksterhuis & Nordgren, 2006; Dijksterhuis & van Olden, 2006). Since implicit memories are overtaken or even shut down by the explicit system it is of utmost importance that the environment is friendly so that the individual doesn’t take conscious control. He or she must be allowed to make mistakes and to take a risk when generating hypothesis and ideas. Otherwise the explicit system takes charge and one loses access to implicit knowledge (Markman, Maddox, & Worthy, 2006).

The four process criteria found to be important in the development of creativity (L. Lindström, 2003) are supported by the model of the implicit memory-system in the following way:

- **Ability to use models:** The student is building a library, partly explicit, partly implicit of solutions to specific problems, a base of patterns that later can be used in a pattern recognition process.

- Investigative work: This is the exploratory phase when the student is trying to find a perspective, a viewpoint from which implicit patterns may match the problem.
- Inventiveness: The importance of a friendly context has been noted already, making access to implicit memories feasible.
- Capacity for self-assessment, knowing one's strengths/weaknesses: A process where patterns are assessed and given a somatic marker and stored in implicit memories. Every task that doesn't give immediate feedback needs this step to be stored with a somatic marker.

Since these "habits of mind" will develop and foster an implicit memory system regardless of the object of design means that the process criterias are not confined to the creative work of art but can be used to enhance creativity and problem-solving in other activities.

## The Expert eye

Of the two identified visual systems implicit memories uses the dorsal route, a wideangle visionsystem with fast, even subliminal, ability to recognize something that has been previously stored (Le Doux, 1996; Pasley, Mayes, & Schultz, 2004). The somatic marker, eg. which memory structure that is evoked will reveal if the visual sight is positive , rewarding or negative, dangerous. This "holistic" pattern recognition will make integrated assessment possible of the kind Dreyfus is writing about. The Expert will be able to see what is relevant and important. The Expert has built a large database of patterns and will be able to handle complicated and fast paced situations. Implicit memories, as the amygdala, will also modulate and amplify explicit memory processes and direct conscious focus / attention towards important objects. Implicit patterns can be sequences of events and will help the expert to adapt to what is happening. Their inferences, assumptions, and predictions allow them, like hockey pro Gretsky, to "*go where the puck is going to be.*" Experts can detect and see patterns and features that novices cannot see. (Benner, 1984; Berliner, 1994; Cellier , Eyrolle, & Mariné, 1997; Chi, 2006; S. E. Dreyfus, 2004; Sternberg, 1998) Several studies gives reason to believe in similar parallel detection systems for other senses like hearing and smelling.

## The Automatic Expert and the capability for dual tasks.

Initially hippocampal, explicit, 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 caudateputamen will also gain from experience and make the expert better in recognizing outcome of perceived contextual patterns. Experts show high accuracy in reaching appropriate solutions, even under time constraint (Berliner, 1994; Chi, 2006; de Groot, 1965; Sternberg, 1998).

The caudate, supports an action based representation that is inflexible (only supporting navigation via the same well-learned route) but have the advantage of mediating fast, automatic responses".(Hartley, Maguire, Spiers, & Burgess, 2003) The low energy consumption of the implicit system will help experts to be active for a long time without being exhausted. This is the neurophysiological explanation of Flow.

*“Expertise leads to proceduralized control that does not require constant attention. Resources are free to devote to secondary task demands”*.(Beilock, Wierenga, & Carr, 2002; Swan, Otani, Loubert, Sheffert, & Dunbar, 2004)

## The Expert Problem solver

Experts exhibit a forward inference/reasoning rather than a backward inference in problem solving. They predict accurately the difficulty of their own problem-solving capability but have problems in predicting difficulties for other experts and novices.(Dhillon, 1998; Priest, 1992; Sternberg, 1998) Several psychological experiments have studied the relations between different modes of thought and the generation of ‘creative’ and original ideas. Conscious thought may be focused and convergent; unconscious thought may be more associative and divergent.(Dijksterhuis, 2006; Nightingale, 1998) Studies of activities in the brain during problem solving show how novices and experts use different structures.(Göcker, 1997)

## Tacit knowledge and intuition.

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. The unconscious use of implicit memories is hidden and since there were no conscious thought during action there will be no conscious memories afterwards. This explains the “sudden wakeup” during routine tasks as driving a car or the loss of memory for unplugging the iron. The idea of “a Somatic Marker” linked to memory was proposed by Damasio to explain intuitive assessment of situations, fear reactions, gut feelings and bias.(Damasio, 1996; Gärdenfors, 2000) This hypothesis has been confirmed, as fMRI studies of the brain support a role of the amygdala in choice behaviour, both in the appraisal of inherent value of choice and the signalling of prospective negative outcomes. Amygdala is used for the recording of emotionally important patterns; if the feedback is missing or is weak, no patterns will be recorded. (Daw, O’Doherty, Dayan, Seymour, & Dolan, 2006; Kahn et al., 2002; Smith, Stephan, Rugg, & Dolan, 2006) Alas intuition and gutfeeling are indicators of familiarity in a context or situation.

## Conclusions and implications

Results from brain-imaging studies and from neuropsychological experiments give strong reasons to believe that experts utilize nondeclarative, implicit memories to perform better. The emotion sensed when a situation is assessed by amygdala or striatum may be what we refer to as intuition or gut feeling and corroborates the models of tacit knowledge by Polanyi and holistic pattern recognition by Dreyfus. On the other side, implicit learning is probably the cause for biases, prejudice and preconceptions. Most of the brain structures involved in expert behaviour are separate from declarative memory structures and cannot be introspected; any verbal description is a construction made from other explicit data. If the knowledge of experts is tacit, new interview methods must be found; maybe the Repertory Grid Technique can be used for the elicitation process. The knowledge experts use a sense of familiarity and automatic evaluation, directly linked to personal experience. This enhanced way of perceiving the world is what the Master is trying to teach the Apprentice and it is almost impossible to apprehend this by oneself using personal reflection or conscious analysis; you need to learn by doing! Further research on experts and expertise using a model of several parallel implicit-memory structures may be rewarding in the field of technology and design education research.

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