Insights into the creativity process

Part 1 : Initial thinking about creativity

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What might one study in a subject to do with understanding the process of being creative and how to foster it in our teaching ? In order to study creativity and its role in education, what are some key questions we could ask about the creativity process ? Some of these questions are as follows :

What are the characteristics of an outcome we call 'creative' ?	What are the changes in what one knows that leads to creativity ? Are there ways of thinking that are more likely to lead to creativity ?	How does the capacity to be creative develop across the life span ?
How can we describe and explain creativity ? What theories of creativity ?	understanding the process of being creative and how to foster it in teaching	Identifying and measuring creativity
Is the capacity to creative innate or is it learnt from one's culture ?	Are particular personality and motivational styles linked with being creative ?	How does the learning context influence creativity ? Are some conditions most likely to lead to creativity ? Can we teach for creativity ?

Useful introductory web sites you can access that examine these questions are as follows:
National Curriculum in Action web site at http://www.ncaction.org.uk/creativity/index.htm and particularly the sections

- What is creativity ?
- Why is creativity so important ?
- How can teachers promote creativity ?
- How can heads and managers promote creativity ?
- Creativity in action examples

The creative process : Being creative

What is creativity ? Creativity applies both to the quality of particular outcomes and the thinking activity that led to them. Thought is creative when it produces something that is both novel and interesting or valuable (Simon, 2001). In its simplest form, it is the birth of "imaginative new ideas" (Miller 1987) or "the imaginatively gifted recombination of known elements into something new" (Ciardi 1956). The ideas need to be appropriate or relevant in terms of an intended purpose.

What does a creative outcome look like ?

Three children were asked to describe the different ways in which they can use a regular house brick (the Alternative Uses task from Guilford's scale). Their responses are below. Decide who you think is most creative. Why ?

Mary	Joe	Cathy

Building a wall	Chimney	Drawing
As a weapon	Pavement	Making noise
Building a fence	Book shelf	Grinding
House	Paper weight	Shop put
Wall	Garden bed edge	Counterbalance
bridge	Pressing leaves	Artificial kneecap

What are your criteria for deciding whether one outcome in an area is more creative than another ?

Imagine a creative outcome. Describe what it is. As well, identify as many adjectives as you can to describe the outcome. Convert each adjective to a verb or a mental action. How do these adjectives help use (1) understand the thinking that leads to creativity; (2) decide whether outcomes are creative; and (3) foster creative thinking ?

Adjectives people use to describe creative outcomes include

- unusual
- inspired,
- intuitive,
- imaginative
- genius

An outcome is creative when it is judged to be both novel and interesting or valuable, particularly by people "skilled in the art" to which the product belongs. (Simon, 2001).

What should an outcome 'look like' if it is to be seen as 'creative' ? Four criteria that are frequently used to decide whether an outcome is creative are listed at The National Curriculum in Action web site at http://www.ncaction.org.uk/creativity/index.htm. It uses the definition of creativity taken from 'All our futures: Creativity, culture and education', the National Advisory Committee's report (DfEE, 1999). The outcome should be

Sufficiently different from the conventional to be novel, original

- Useful, functional, achieve the purpose for which it is intended
- The purpose should be valued or potentially
- The outcome suggests the use of imagination; there is something about the outcome that suggests 'imaginative flair', is associated with an element of surprise or unexpectedness

Creativity may be an outcome when an individual re-interprets or transforms what she / he knows, leading to an extension of experience or a realization of new dimensions or perspectives. The activity may either be simple, reflecting the cognitive development and environment of the individual or it may reflect a high level of reflexivity and contextual complexity (Pickard; 1990).

What do you do to be creative ?

To get an insight into what you do when you are creative try each of the following open –ended tasks. When you have generated some outcomes, select those you think are most creative. What did you do to produce the more creative outcomes ?

Task	Your outcomes	What did you do to produce the more creative outcomes ?
Give as many unusual uses as you can for a spoon, a piece of cotton, a jar.		
Find a remote fourth word that links moon, cheese, and grass		
Here are three sets of items: • table, chair, lamp, bed • banana, pineapple, orange, peach • telephone book, search warrant, marriage certificate, map Combine these categories to create a new, superordinate category and name the new category		
Our experience of an event is more beneficial than our memory of it. Would you agree ? What reasons would you give to support your decision ? What thinking actions did you use ?		

Look back over your responses.

To decide how creative your responses are in each case, what criteria would you use ?	
Identify the thinking strategies you used in each case.	

The National Curriculum in Action web site at http://www.ncaction.org.uk/creativity/index.htm gives an introductory discussion of that creativity looks like in the classroom? It notes that when pupils are thinking and behaving creatively in the classroom, they are likely to be:

- questioning and challenging the conventional ideas and don't always follow rules; they think independently, challenge conventions and their own and others' assumptions and ask unusual questions that are often surprising.

- making connections and seeing relationships; they make 'far transfer' of their knowledge, often by using analogies and metaphors, spontaneously look for trends and see patterns that others may not see.

- envisaging what might be; they imagine and visualise options and possibilities, ask 'what if?', intentionally look at and think about ideas from multiple points of view.

- exploring ideas, keeping options open; they play and experiment with ideas, think intuitively, anticipate and overcome difficulties, follow an idea through and keep an open mind, adapting and modifying their ideas to achieve creative results.

- reflecting critically on ideas, actions and outcomes; they monitor and review progress, seek and use feedback, make perceptive observations about originality and value.

We can explore how well these describe and explain creative activity in the following example of creative thinking.

Example of creative thinking

To get a 'feel' for what we mean by creative thinking, it is useful to look at real life instances. The one examined here come from corporate rather than educational contexts (Robinson & Stern, 1997). It enhanced the knowledge of organisation in which it was developed, and beyond. It provides us with data for analysing this process.

It is about a Japanese food technologist, Tomoshige Hori, whose job was to investigate ways of making dairy products more nutritious and tasty. A problem in making cheese was identifying the time when the milk curdled. It was determined by skilled workers making subjective judgments as they looked at a vat of milk. After attending a symposium on how to measure thermal conductivity of liquids using a 'hot wire', Hori began to question whether this procedure could be applied to milk curdling. Early experiments he did suggested it could be possible. Although his boss discouraged him from continuing, he did wrote paper re the outcomes of his research. With the interest this attracted, he approached his management again and support was provided. His discovery has now been applied throughout the industry.

This instance fits the commonly held criteria of creative thinking. It involves creative thinking outcomes that have been trialed and evaluated in the particular contexts. The thinking of both Hori led to novel ways of doing things. It was not, however, only creative. It involved a high level of analysis, trialing and evaluation. The outcomes were judged as relevant and appropriate, preferable to existing practice. This, while they were divergent, the outcomes were also convergent in that they were aligned with where the company was going.

What happens to produce a creative outcome

In the examples above the creative outcome was the result of two areas of knowledge becoming linked for the first time, generating new ideas. In Hori's case, two previously unlinked concepts, milk changing to cheese and using a 'hot wire' to measure the thermal conductivity of liquids became linked.

Prior to creative act	milk changing to cheese	a 'hot wire' can be used to measure the thermal conductivity of liquids

After creative act	Could the point at which milk changes to cheese be detected using a 'hot wire' to measure the change in the thermal conductivity of the milk

Once the new possibility had been formed, it needed to be trialed and evaluated. Hori had to check to see that no-one else had already made this discovery. He also had to communicate it to peers and to convince them of it.

Creative outcomes generally involve linking two or more ideas, often initially by an intuitive judgment. Sometimes the ideas just seem to be in the person's thinking space at the same time and become linked in a tentative or 'possibilistic' way.

Many people who have produced creative ideas describe how making mental images of the ideas, visualising or picturing them in particular situations, using real life ideas to represent them, helps the creativity. It seems that the visualising allows several possibilities to be 'seen in the mind's eye' at once. Imagining the ideas acting or being acted on can add an element of dynamism that also assists creative thinking. Thinking about the ideas

Once the intuition or possibility has been evaluated critically, either by testing or by applying relevant logic, it can then be linked with logic or reason to what the person (and often the culture) already know.

What does creative thinking do ? Unpacking creative thinking

Activity : What are features of the creative thinking in which Hori engaged ?

Creative thinking refers to the actions people apply to their knowledge to generate the creative outcomes and to test them. They include

- the synthesising actions that are used to link or integrate ideas to generate novel outcomes
- the critical-evaluative actions that are used to evaluate and assess the novel ideas and
- balancing the synthesising and critical-evaluative actions.

Creative thinking involves two components that operate interactively :

- novelty thinking about current issues and problems
- deciding whether the novel outcomes are useful, better, preferable.

It has various characteristics:

- it has a systems perspective; the thinking is referenced or 'located' within a culture and takes account of factors within it. Hori located their thinking within the work cultures of their organisations and understood the implications and outcomes of their thinking for the company. Hart began with an existing problem while Hori saw a way of improving the current processes.

- it is intent-focused and intent-driven. Hori had an intent that focused their energy and attention to achieve their goals. Hori, for example, resisted the negative feedback that could have distracted him and concentrated on achieving the goal.

- it involves 'intelligent opportunism'. Hori displayed an openness to new knowledge, ways of thinking and experiences which allow them to implement novel, more efficient strategies. Intelligent opportunism involves being able to recognise the potential of new information and to make opportunities for realizing its knowledge potential.

- in involves thinking in time; it links the current reality with possible futures. Hori's thinking began with their interpretations of the present reality in their organisations. From this they

framed up possibilities, intents or hypotheses about future practice that they investigated test them efficiently and integrate creative and critical thinking.

Some of the activities used to assist creativity to solve problems in business are provided on the web page http://www.quantumbooks.com/Creativity.html#G5. One aspect of creative thinking, Creativity and unpredictability, is examined by Margaret Boden at the address http://www.stanford.edu/group/SHR/4-2/text/boden.html.

What do people think creativity is like ?

The Ephilosopher chat room web site http://www.ephilosopher.com/phpBB_14-action-viewtopic-topic-3174-start-105.html reports the dynamic dialogue of individuals discussing whether *Can creativity ever be explained?* The dialogue is particularly insightful about what people believe creativity is. The following excerpts stimulate further discussion and reflection.

- You can be creative without being successful, and successful without being creative

- Success is a result. Creativity is an input, at the same basic level as luck, or money, or skill. Things precede other things in cause and effect. Things are composed of other things. Metaphors to help:

    - Say that success is a pie being eaten by people in a diner.....luck and fame and creativity and skill all go into that yummy success pie.

    - A nail goes into a board. So does paint. A nail is not paint. Creativity is not luck.

- Compositional thinking please: because creativity touches success, and success is touched by money or supportive family or luck, that does not mean it is any of those things. That's why they have different words.

- They don't just touch each other, they often intertwine in a way that a distinction between them is impossible. There's a difference between them, but it's vague. (We have to remember that "success" is a rather relative concept.)

- When you create, you put unrelated things together for a purpose. You can be either successful or unsuccessful in reaching that purpose. What is 'success' on the other hand is context-relative, usually socially attributed. So, 'creativity' implies the social attribution of success.

- There are degrees of creativity. But where we get our standards from and whether they are great ones is open to debate.

- Many's the artist who can paint a nice landscape, but is destined for the graphic arts dept. of a **book** publisher, because they are missing a new vision that will rivet the attention.

- And what is the "new vision that will rivet the attention" substantially is determined by the appetites of the masses, not by the personal qualities of the artist. It is chaotic.

- But you are also your own audience - the criteria by which you accept your own work is affected by social environment you are embedded to. Like it or not, you always compare yourself and your doings to that of others, in some way or another. Especially to those who are compared as successful in their similar doings.

- Let's say you compose a song on guitar for your own amusement (I do that a lot). Now what you consider good-sounding riffs are actually those you are already familiar with in some way (a fact from psychology), from the music you are usually listening for instance. So, thus you compose by comparing to the readily existing music, without even noticing.

- This way the success - the accumulation of attention, for instance - determines creativity.

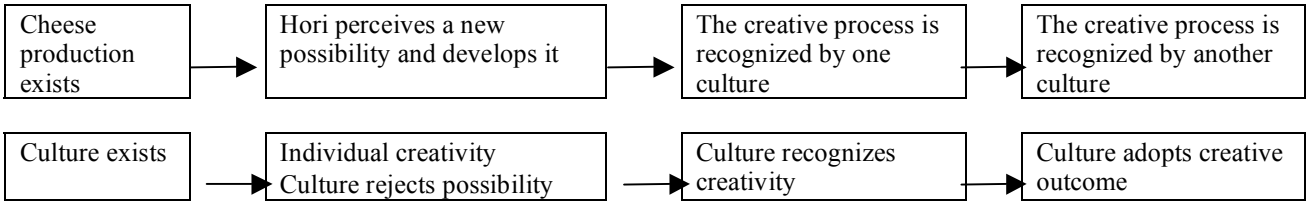
- Markus, go to a dictionary. In Webster's, it's meaning number 2 under 'creative': original, imaginative It isn't even in the same concept space as fame or popularity.

- Sure I compare myself and I pay attention to what other people think about my music but I don't use that as a reason or basis to create. I've already created the music the only thing in question is whether it is accepted by others or not. When making a song I go through a main idea and hours of trial and error to see what fits till I come up with a complete song-some of the choices may be attributed to my social environment but the whole package is my creation. Just the same with writing, you never invented the words and you even borrow some coined phrases and ideas but the whole **book**, poem, story is yours.

Does creativity exist at the individual level or at the cultural level ? Creativity can be seen to exist at different levels: the individual level and the group or cultural level. In order to unpack and analyze various issues to do with creativity we need to clarify what happens at each level. In particular, what role does the culture have on creativity ? Various questions one can ask include

- In what ways is creativity a response to one's culture at any time ?
- In what ways can a culture foster and restrict creativity ?
- Can an outcome be called 'creative' if it meets the criteria at an individual level but is not creative at the cultural level ?

Hori's example shows one way in which cultural and individual creativity interact.



We can describe creativity at the two levels as follows:

the individual level	the cultural level
thinking and activity is described as creative if it new and meaningful for individuals	the creative processes and products, whose novelty and effects refer to the social and material environment , the culture or the development of mankind in general
Personal creativity; an individual re-interprets or transforms knowledge, leading to an extension of experience, a realization of new dimensions or perspectives. The activity may be simple, reflecting the cognitive development and environment of the individual. Equally, it may reflect a high level of reflexivity and contextual complexity.	Public creativity is not different in nature from personal creativity. It becomes public when the outcomes or products of a person's transformational activity extend the experience and knowledge of others" . New products after a time become self-evident and "natural" in daily use.
psychological, sense of creativity called "P-creative" (Boden ; 1990)	historical sense of creativity, called "H-creative".

The cultural referential level is more differentiated, for example in reference to peers or groups, to culture, locally, regionally, globally or historically meaningful and effective.

Whether personal creativity becomes public depends on the quality of the transformational product. Children may produce solutions and products that surprise adults but these are usually unlikely to enrich the culture. They don't have the level of expertise necessary for emergentive innovations in an area.

The quality of personal creativity changes during the development of transformational activities and increases at the same time as the possibility that the individual will contribute to public creativity.

To what extent does classroom practice usually teach creativity ?

It is generally agreed that the regular classroom lacks creativity (Dodds 1998; Kern 1997; Gilbert, Prenshaw, and Ivy 1996; Ramocki 1994; Titus, 2000) Systematic creativity training can enhance creative thinking (e.g., Dodds 1998; Gilbert, Prenshaw, and Ivy 1992, 1996; Jacobs 1984; Ramocki 1996). Research has been limited to the effectiveness of specific idea-generating techniques (Jacobs 1984), exercises (Ramocki 1996), and courses (Dodds 1998; Gilbert, Prenshaw, and Ivy 1992,1996) designed to enhance creative thinking.

What is the relationship between teaching creativity and cultural factors and issues ?

- Can teaching creativity encourage students to question and possibly threaten cultural tradition and the cultural status quo ? Can creative education be used to achieve political and transnational goals ?

- Is creative education an instrument of social critique or does social critique drive creative expression? Can we divorce the creators from their creations in the process of judging the creations ? Does valuing and appreciating Wagner's creativity imply an incipient predisposition towards racism?

- Under what conditions does it becomes more wholesome, effective and socially healthy for students to assess themselves ? We need to create more authentic settings for students to justify their work, for example by exposing them to interaction with real audiences.

What creative people say about being creative.

Herbert A. Simon is University Professor of Computer Sciences and Psychology at Carnegie Mellon University. In 1978 he was awarded the Nobel Award for Economics and in 1975 the Turing Award of the Association for Computing Machinery with Allen Newell). In 2001 he wrote an excellent article describing creativity in the arts and the sciences (Simon, 2001).

Simon notes that

- Newton proposed two theories to explain his creativity:
  - he solved difficult scientific problems "by dwelling constantly upon them."
  - he attributed his successes to "standing on the shoulders of giants."
  - his "inspired" results followed from commonplace activities.
- Pasteur noted that "Novel ideas come to the prepared mind."

Many of the historical accounts by scientists and inventors of their efforts to solve technological and scientific problems note the role of visual imagery and visualisation in the creativity and innovation process. Many of the creations involved a potential solution appearing as an image. The visualizations seemed to be instantaneous and appeared in a completed, whole structure. Because of their nonverbal quality, they were often difficult to communicate to others in words. Shepard (1988) lists several of these:

- James Watt, who created the steam condenser, reported that images were suddenly arranged in his mind, particularly when he was reflecting the inefficiencies of the Newcomen engine which wasted more than half of its energy source. While on a Sunday walk through his village almost instantly he linked the elasticity of steam and redirecting the steam flow and visualised what a possible engine might look like..

- Michael Faraday visualise the lines of force that surrounded magnets and electric currents and used this to understand how magnetic fields could generate electricity. Faraday disliked using language and writing and had little mathematical knowledge (Kendall, 1955; Koestler, 1964).

- James Maxwell used mental imagery and concrete model building to solve problems to do with electro-magnetic waves (Beveridge, 1957).

- Oliver Evans claimed that he saw, while resting in bed an image of the automatic flour mill he later invented in his mind eye actually operating, implementing each of the phases of the work (Ferguson, 1977).

- Friedrich Kekule, discovered the molecular structure of benzene while gazing into the flames of a fire while the atoms danced before his eyes (Sommer, 1978). He imagined the moving molecules in an image that resembled a snake biting its tail. This image led to the discovery of the ring-like molecular structure of benzene.

- Albert Einstein used visualization and new mental models and tools mental to deal with problems in moving images (Ferguson, 1977; Shepard, 1988). He had difficulty with language. At the age of sixteen, he imaged himself riding on a beam of light and what things would look like as he traveled on it. This helped him to think about light as if it were stationary. To understand more about the speed of light, he compared how two people, one on a street and the other in a moving truck would see a light flashing inside the truck. What single event was most helpful in developing the Theory of Relativity ? Einstein identified : "Figuring out how to think about the problem."

- James D. Watson who used three-dimensional models to produce DNA module

- Alfred Wegner built his theory on the movement of the tectonic plates by visualising the interlocking of the continents (Rieber, 1995).

- Jacques Hadamard, a famous mathematician, reports using visualisation to solve problems. He found imagined concrete structures much more useful than algebraic symbolism (that often slowed his thinking, and rarely thought in words (Hadamard, 1945).

- Wilbur Wright used visual imagery to solve the flight control problem prevent rolling by Flyer 1.. While serving a customer in his bicycle shop, he played with an empty box which contained an inner tube. As he twisted the ends of the box in opposite directions he saw in

his mind's eye a link with the wing warping system of the biplane. This solved the problem of rolling. (Rieber, 1995).

- Omar Snyder experienced the sudden appearance of a visual solution to a problem while working on the atomic bomb project in 1943. (Shepard, 1988). The scientific team had a problem with the reactor; they could not achieve both uniform heat with the uranium in enclosed cans and maintain gas-tight seals. Snyder 'saw' the solution suddenly and unexpectedly as he walked passed the water cooler. He saw the fuel element with its three metal composition as a visual image. Using this and without other plans, he made the element, which solved the reactor problem.

- Jonas Salk who developed the polio vaccine after waking one morning with an intuitive flash.

- Newton developed his 'Laws of gravitation' and the concept of universal gravitation after he combined two apparently unrelated images; he saw at the same time the falling apple and the moon in the sky. This led him to wonder whether the same laws applied to both the falling apple and the moon orbiting the earth. From this he develop the laws of mechanics and established mathematical analysis and modeling as the principal foundations of science and engineering.

- The link between magnetism and electricity was first suspected as the result of an public experiment that 'went wrong'. Hans Oersted, a Danish physicist and philosopher, in a public lecture in 1819, was attempting to demonstrate the "well known fact" that electricity and magnetism were independent of each when the experiment 'didn't work'.

  He showed this by placing a compass needle near a wire that would carry an electric current. When the electricity was turned on, the magnet deflected. The discovery of this connection changed the direction of electrodynamic research and provided the knowledge for many of our modern day appliances. Oersted's was not totally accidental and spontaneous. He believed that nature was systematic and unified and that it could be possible that a connection existed between electricity and magnetism.

There are three major aspects of these visualization experiences that led to creative outcomes:

- the outcomes appeared as a visualised image, regularly referred to as being "in the mind's eye". It is well-defined and can be easily remembered and used.
- the images appear suddenly and instantly in a wholistic way, rather than building up bit by bit.
- the outcomes often appear during activities unrelated to the task rather than when the creators are thinking consciously about the topic. It is as if the creators have, at the time of the awareness, 'disengaged' their rational and ordered thinking about the topic. They may have gone for a walk, gazing into a fire or resting. During these times they have often allowed ideas to 'run wild' in their minds.

Other examples creativity in science and technology are provided on the web page http://www.quantumbooks.com/Creativity.html#G5.

Does creativity play as strong a role in the sciences as in art? This question is discussed on the web site http://users.drew.edu/~ejustin/creativity.htm. The 'for' case provides several useful links to sites that examine the effective use of creativity in business and science in historical innovations. The 'against' case acknowledges that creativity does play an important role in science, but that more is involved in art and that in art the type of creativity is a 'no-holds-barred, anything-goes'

type of creativity.

As well as having expertise in the areas of their creativity, these findings indicate that visual imagery is a key contributor to creativity for many people. Their expert knowledge of the topic has the aspects of knowledge that will become the creation. The visual imagery assists them to make potential links between aspects of this knowledge. As well, many were less able in their use of language and engaged in problem solving play with concrete toys, mechanical models and puzzles (Shepard, 1988)

How can we research what people do to be creative ?

More generally, you can get an insight into how many scientists and thinkers made their creative discoveries through autobiographies. You can read brief descriptions of how these thinkers made creative discoveries by accessing http://www.time.com/time/time100/scientist/ . Thinkers include

- Leo Baekeland
- Francis Crick & James Watson
- Enrico Fermi
- Robert Goddard
- John Maynard Keynes
- Jean Piaget
- Alan Turing

Tim Berners-Lee
Albert Einstein
Alexander Fleming
Kurt Gödel
Louis, Mary & Richard Leakey
Jonas Salk
Ludwig Wittgenstein

Rachel Carson
Philo Farnsworth
Sigmund Freud
Edwin Hubble
William Shockley
Wilbur & Orville Wright

Herbert Simon also provides us with an insight into this question. In Simon (2001) he asks : What mechanisms account for the outcomes we call creative? He seeks explanations that show scientifically these mechanisms. The sources of evidence he sees that meet the scientific criteria for creativity in both science the arts include

- the history and sociology of the topic using scientists' and artists lab notebooks, life stories, and correspondence.

- cognitive psychology, that links case-study evidence to general psychological mechanisms that in turn have led to computer models of creative processes.

He comments first that we can explain outstanding scientific and artistic achievements without proposing magical, or even unique, mechanisms. These achievements are at the upper end of a continuum of common human mental activities. They are not qualitatively different from the activities that appear in more commonplace problem solving, decision making, and design. As evidence he notes the points made by Newton and Pasteur above.

He asks how the complexity of human thinking can be researched scientifically and makes a valuable analogy between computers and brains to help understand how brains operate. We know little about the biological structure of the brain, although we understand some of the electrochemical structure and operation of neurons. Both computers and brains handle information by recognising, manipulating and outputting symbols and that, just as computer programmers can understand programming without understanding the hardware and scientists could understood chemical reactions before they knew quarks existed, so we can understand thinking without understanding fully brain architecture. The data we have support our models of thinking come from (1) the detailed analyses of problem solving behavior by individuals and (2) computer programs that are solving the identical learning, problems in cognitive simulation contexts.

His third comment relates to the concept of ‘expertise’. He uses this later to show that creative people are experts in the area in which they are creative. He notes three broad propositions: (1)

experts are strong problem solvers in the domain of expertise, but not necessarily in other domains; (2) their stored knowledge in the domain of expertise allows them to recognize familiar patterns that have been seen before and to link them with what is known and (3) that this level of knowledge in any area requires at least ten years of intense application to be learnt.

His fourth comment relates to creative thinking. He notes that evidence from diaries and laboratory notebooks and from psychological laboratory and computer simulations of creativity suggests programs suggests a consistent picture of how the creative process works in the sciences and in the arts. Creative people have a greater bank of knowledge in the domain of their creativity and this bank is indexed with patterns that allow it to be easily used in creative situations. They spend a lot of time learning and thinking about this knowledge. As well, their creativity builds on the creativity of those who have gone before. It is possible to see the steps or jumps in their thinking that led to the creative outcome.

His fifth comment relates to evidence of creativity in science. Faraday's activity that led him to see that a moving magnetic field could produce an electric current is reviewed. Simon reminds us of the questions Faraday asked himself, the experiments that didn't and did 'work', his surprise with some of his observations, how he experimented in the absence of a theory of the phenomenon, the incremental steps he made and the descriptive ways in which he described his observations (by using analogy with everyday events). He notes how Faraday (1) detected changes in the phenomena as he altered his apparatus; (2) thought about the novel patterns he observed in a large number of simple but effective incremental steps; and (3) began to build up a picture of the magnetic lines of force that the electric wire was cutting.

He identifies similar features in stories re the experiments used by (1) Kreb to discover the role of ornithine in synthesising urea; (2) the Wright Brothers in building an airplane that flew; (3) the Curies to discover radium; and (4) Fleming to discover the bactericidal action of penicillin. He notes how in theses the surprise of a prepared mind that scrutinizes a sequence of experimental phenomena and sees one that violates the expected outcomes. In these examples the investigators are the expert problem solvers, making highly selective searches through an immense problem space, punctuated by recognitions of (often surprising) features in the phenomena that evoke stored information and turn the search in new directions.

He notes that evidence that computer simulation of creativity can simulate the creative thinking of the original scientists. He illustrates this using the example of Kepler's Third Law of planetary motion, which links the period of revolution of a planet about our Sun to its average distance from the Sun. Kepler with no theory to explain the motion but data he collected, initially produced an erroneous law, and then the correct one. A computer program called BACON, designed to find patterns and laws in data took Kepler's data and generated initially his incorrect law and then his correct version. Its 'thinking' matched that of Kepler.

BACON has also been used to rediscover other important laws of nineteenth century physics and chemistry, using only the information used by the original discoverers. It uses the same 'thinking' as they used, searching a problem space and looking for familiar patterns. The historical information and the computer simulations show the processes of scientific discovery involves pattern recognition and selective search.

His fifth comment relates to evidence of creativity in the arts. He suggests that for creativity in the arts, the creative process is much the same as in science. As evidence he uses the computer program Aaron, designed by the painter Harold Cohen to produce drawings or paintings of aesthetic interest and the qualities it needed to evoke meaningful responses from viewers.

Aaron has evolved for more than 25 years. It creates a painting independently, each successive line or stroke determined by its inspection of the painting's current status. It 'decides' to introduce new objects or to elaborate objects already present by judging the balance or imbalance of the composition until it reaches a point where other criteria tell it that the painting is complete.

Its early work was non-representational; it only arranged abstract objects in space. It now can now represent items, for example, human figures to whom viewers attribute meaningful social interactions. While its actual painting is automatic, its methods come from its programmer.

Like the programs for scientific discovery, Aaron uses search and pattern recognition. Its stored information can be used with patterns to select the next step to modify the drawing. When it 'sees' an imbalance in a painting it can decide to construct and locate a new object to restore the balance.

Similar developments have occurred in music. Computer music, judged to be aesthetically interesting by sophisticated musicians has been produced by analyzing the arrangements of tones that make up musical patterns in various periods and cultures, and in showing how computer programs can detect such patterns in music. The design processes used by composers to compose a new fugue are quite similar to those indicated in the records of scientific discovery.

Simon's sixth point is that the evidence about creative thinking suggests that it is basically what individuals use in their every day thinking and that we don't need a separate theory of creative thinking but a theory that identifies the conditions under which regular thinking is more likely to lead to outcomes that are novel and valuable or interesting. Two conditions are: (1) a large and properly indexed body of knowledge and (2) skills of selective, heuristic search in the domain of expertise, and careful examination of new phenomena disclosed by such search.

Simon's seventh point relates to the use of the two hemispheres during creative thinking. He notes that the two hemispheres do not have identical functions; most memory for language, for example, is stored (in right-handed people) in the left hemisphere, while certain processes associated with visual imagery are carried out in the right hemisphere.

He expresses cynicism in relation to the belief that two hemispheres lead to two distinct forms of human thought: (1) the "holistic," "intuitive" thought of the right hemisphere; and (2) the "analytic," "logical" thought of the left hemisphere. In this view, the right hemisphere manages artistic and other types of "creative" activity and the left manages scientific and technology outcomes. He notes that the empirical evidence simply does not support the idea that any complex cognitive tasks are carried out in a single specialized hemisphere. Histologically the hemispheres are similar and, in cases of early brain damage, either one can sometimes assume with little or no deficit the functions of the other. The two hemispheres do not divide us into two kinds of human beings, each with our specialized ways of thinking. We can dismiss at least this particular potential source of human disparity

Theories of how creative outcomes are developed

Various types of theories have been proposed. We will examine the following:

- The componential theories of creativity. These identify the aspects or components of
- The Stage Models of Creativity
- Sternberg's model of creativity : How individuals decide how to use what they know
- Personality and motivational theories of creativity
- Thinking skills lead to creativity

Thinking about creativity

In our introduction to creativity we have assumed various propositions and values about creativity. We have talked about individuals being creative and outcomes as being creative. We have assumed that creativity is valuable and something that should be fostered and supported. We have assumed it can be studied in much the same way as we study the learning of mathematics.

At this early point in our consideration of creativity it is useful to examine some issues that may see antithetical to these propositions and attitudes :

- Milgram (1990) argued that creativity is a concept whose time has come and gone.

- Czikszentmihalyi (1996) proposed that creativity is a diffuse category of positive judgment in the mind of critics.

An implication of Czikszentmihalyi's proposition is that if some people did not judge the outcomes of others, we wouldn't have the concept of creativity. It raises the question of whether the people who are seen by others as being creative are aware that they are creative before they get this recognition. If they don't see themselves as being 'creative' at particular times, is it sensible for others to see them as being creative at those times. Czikszentmihalyi's proposition prompts the issue of 'how real' creativity is as a construct.

Is it, in fact, largely a creation of our Western-based cultures ? Do other cultures have a matching concept or are they more likely to recognise that individuals differ in what they produce and think, and leave the distinction there ?

One is prompted to ask whether a culture benefits from developing such a concept ? Is it, for example a useful tool for the continuity of a capitalist-enterprise oriented culture that focuses on evolving markets ?

Milgram 's proposition, too, is interesting, given the contemporary international focus on knowledge as a commodity. Obviously, the extent to which it can be enhanced (that is, new ideas created) and the new ideas converted into specific process or items (that is, innovations and enterprise) are seen as important in the Twenty-first Century world. Where does Milgram 's 1990 proposition sit in the virtual cyber world of 2005 ?

Consider these propositions in relation to the course we will consider.

The path that I have put together for us visits the following topics ?

	Key issues we will examine
The creative process : What do we as a group know about being creative ?	• What is creativity ? • What do you do to be creative ? • What does a creative outcome look like ? • Examples of creative thinking • What happens to produce a creative outcome • What does creative thinking do ? Unpacking creative thinking • To what extent does classroom practice teach creativity ? • What is the relationship between creativity and cultural factors? • What creative people say about being creative. • How can we research what people do to be creative ? • Theories of how creative outcomes are developed • Thinking about creativity

What theories have been proposed to describe and explain creativity ?	
The componential theories of creativity	• Amabile's and Urban's componential theories of creativity • Values of the model: it can be used to • What would each component look like in teaching ? • Education for creativity

The Stage Models of Creativity	• Wallas' stages model
	• Cropley's stages model
	• Creative problem solving
	• The CPS process: pedagogical implications and classroom application
	  • Problem Identification
	  • Problem Delineation
	  • Information Gathering:
	  • Idea Generation
	  • Idea Evaluation and Refinement
	  • Idea Implementation

How individuals decide how to use what they know	
Personality and motivational theories of creativity	• Personality and motivational theories of creative achievement • Characteristics of Creative Producers • The Primacy of Motivation in Creativity). • Motivational Controls for Self-Regulating the Motivated Mind • Comparing the Motivated Mind • Researching the Motivated Mind
Thinking skills models of creativity	• Planning is a key aspect of creativity • Creative thinking in science • Thinking actions
The conditions most likely to lead to creativity	• A microscopic on what you know • What happens to produce a creative outcome • Creativity and Intuition
The creativity process : What happens to the knowledge ?	
General Development of creativity in childhood	• The gradual development of creativity has been neglected • Development of creativity in infants • Creativity development in the early years of formal education • Creativity developmental beyond the early years of formal education. • Family conditions and development of creativity • Creativity developmental during the adult years.

Identifying and measuring creativity	•Issues that relate to the assessment of creativity ? •Why assess or measure an individual's creativity •When you are assessing creativity, what do you measure ? •In order to assess creativity, what outcomes or processes do you use ? •How can you judge creativity in different subject or domain areas •Reviewing creativity assessment scales. •Assessing creative outcomes or products •What do creativity tests measure ? •The Creative Process •The Creative Person •Overview of creativity assessment procedures
Teaching for creativity	•Applying the componential and stages models of creativity to teaching •Fostering intuitive thinking in our teaching •The conceptions of knowledge that encourage creative thinking •Building creativity into topics we teach

Simon H. A. (2001) Creativity in the arts and the sciences The Kenyon Review 23, (2), 203-220.