



SUBJECT PERSPECTIVES ON CREATIVITY IN HIGHER EDUCATION WORKING PAPER APRIL 2005

CREATIVITY IN EARTH AND ENVIRONMENTAL SCIENCE TEACHING AND LEARNING Norman Jackson

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Readers are invited to endorse, challenge, change or add to the statements so that they embody more fully and accurately the meanings of creativity as it is understood within the discipline. *Please send further contributions to the author Norman.Jackson@heacademy.ac.uk.*

Introduction

The Higher Education Academy's is trying to encourage higher education teachers and subject communities to consider the role of creativity in students' learning and their experiences of learning¹. Underlying this attempt to engage higher education are the assumptions that:

- ∅ Being creative is present in all disciplinary learning contexts, although we rarely use words like creativity to describe such things.
- ∅ We all need to be creative (inventive/adaptive) in a world that is constantly changing: a world that also requires us to change/adapt.
- ∅ Apart from those disciplines that explicitly recognise creativity as a central feature of their identity (like the performing arts and design), creativity is largely implicit in discussions about teaching and learning. However, teachers do value creativity, originality, flair and imagination in their students' learning. Indeed some teachers believe that creativity is one of the hallmarks of excellence in learning and performance.

Underlying our project is the desire to show that **creativity is an important part of being an earth and environmental scientist**. To test this proposition an email survey aimed at gaining insights into how higher education teachers understand creativity in the context of their professional practice (both disciplinary practice as earth scientists and their educational practice as teachers) was conducted through the agency of the Higher Education Academy's Geography, Earth and Environmental Science Subject Centre (GEES). Twelve higher education teachers participated in the survey and their contributions are greatly appreciated (see acknowledgements). The survey results were supplemented with a small number of face to face conversations.

Questions used to prompt discussion

- ∅ What it means to say that someone is creative? (any context)
- ∅ How are Earth and Environmental Scientists creative?
- ∅ What is it about Earth and Environmental Science that stimulates / encourages teachers and students to be creative?
- ∅ What is it about earth and environmental science as it is taught and studied which prompts students to be creative?
- ∅ How do higher education Earth/Environmental science teachers help/enable students to be creative?

¹ <http://www.heacademy.ac.uk/creativity.htm>

- Ø What forms of teaching are encourage/enable students to be creative?
- Ø What contexts/conditions for learning encourage/enable students to be creative?
- Ø How we recognize and assess creativity in earth and environmental science education?
- Ø What aspects of creativity can be assessed / cannot be assessed very easily?
- Ø What sorts of evidence do we draw on in order to evaluate creativity?
- Ø What criteria do we use to evaluate creativity?

The importance of disciplines

'Creativity cannot be understood by looking only at the people who appear to make it happen... creative ideas vanish unless there is a receptive audience to (appreciate), record and implement them. And without the assessment of outsiders, there is no reliable way to decide whether the claims of a self-styled creative person are valid. According to this view, creativity results from the interaction of a system composed of three elements: *a culture* that contains symbolic rules, *a person* brings novelty into the symbolic domain, and a *field of experts* who recognize and validate the innovation. All three are necessary for a creative idea, product or discovery to take place.' (Csikszentmihayli 1996 p6).

Adapting this conception of a 'system for creativity' to a higher education teaching and learning context:

- The culture is the subject domain with its specialised knowledge base, symbolic language, applied practices and ways of thinking and performing.
- The teacher is the representative of the field. The teacher's role is to help create conditions that encourage students to be creative (i.e. support creative enterprise) and act as evaluator (process and the products and outcomes of the process).
- Students are the people who individually and collectively bring novelty into the symbolic domain. In effect they are serving an apprenticeship to develop their creative potential for the domain and beyond.

Earth and Environmental Science Perspectives on Creativity

What it means to say that someone is creative (any context)

Earth and environmental (e/e) scientists associate creativity with:

- thinking and being independent or individual
- harnessing the imagination to generate new ideas
- thinking out of the boxes we normally inhabit, looking beyond the obvious, seeing the world in different ways
- doing something with the imagination to produce new things, doing things no one has done before, doing things that have been done before differently
- striving for some sort of deeper understanding or relationships and connectivity
- playfulness, experimentation and taking risks.

'Without some contradiction within oneself, there can be no study; that, indeed, is the essential nature of study. To put it differently, one has some place that is dark, or obscure, or vague, or puzzling within oneself, and one tries to find some light in it. Then, when one has found a ray of light, one tries to enlarge it little by little so that darkness is gradually dispelled. This, I feel, is the typical process whereby creativity shows itself.'²

'This definition of creativity allows for a variety of processes and speeds. Physicists and mathematicians tend to focus on a brand new insight, a new way of doing something, and to discount syntheses of existing material. But, the more gradually process of synthesizing experiences to provide answers to new questions is also creative, and is more applicable to the biological and geological [Earth and Environmental] sciences. We don't have a historic legacy of thinking about our creativity like the mathematicians and physicists, and any easy measures are

² Yukawa, H. (1973) Creativity and Intuition: A Physicist Looks at East and West and earlier works

measures of productivity, not creativity. Judgment of creativity requires a value judgment, not simply numerical counting. We don't judge Einstein creative by the number of papers he published, but rather, by *the beauty of his concepts*. It seems absolutely essential that in order to maintain creativity, we have to periodically move out of our own masses of fixed ideas into the unknown. In the earth sciences, we have the opportunity to do this simply by exploring our planet, and now, other planets. We must recognize that stimulus and surprises are important. We as individuals should try to break down the barriers that our own frameworks erect and allow ourselves to be open to surprises.³

Things that Earth and Environmental Scientists do that are creative

Compared to more analytical, deductive, abstract physical sciences earth and environmental science is a largely inductive and tangible science. The cultures of the subjects that make up the earth and environmental sciences disciplines build cumulatively on experience and induction rather than purely on analysis and deduction.

Earth and Environmental scientists combine analytical/deductive (**convergent**) ways of thinking with more inductive and **divergent** ways of thinking drawn from experience (rather than text books).

Thinking is rich in the generation of ideas or hypothesis (**ideation**) that can be used to construct stories (possible interpretations of evidence) that can then be tested and evaluated.

The **imagination of the earth scientist** is dedicated to thinking about and reconstructing past worlds. These worlds are mental models of what might have existed based on the interpretation of evidence and the application of the basic principle that the present is the key to the past. The **imagination of the environmental scientist** is rooted much more in understanding the present and recent past and projecting the known into the unknown future.

The nature of the earth and environmental science is such that practitioners are confronted with **complex interfering systems** (physical, chemical and biological) **that have to be visualised and understood holistically**. This type of thinking stimulates the imagination in order to comprehend the complex associations, relationships and effects involved. The quest to understand and explain how complex earth systems work is the source of problem finding and working in the discipline. The complexity of systems requires practitioners to think inter-disciplinarily: the discipline is pre-disposed to borrowing/adapting/using ideas, constructs and methodologies from other subjects. The blending and intelligent use of these different sources of knowledge to solve particular problems is potentially another source of creativity.

Illustrations of the way Earth and Environmental Scientists are creative

Exploration – the application of knowledge in higher education is often formulated around the quest for understanding or solutions to questions? Earth and environmental scientists are good at finding and progressively defining and understanding problems that relate to their domain. In many problem working situations there are not single solutions but a number of possibilities the evidence for which has to be carefully presented and evaluated. Problem finding and definition requires both divergent and convergent ways of thinking.

Enquiry-led learning through which a continuous stream of questions are posed encourages imaginative divergent thinking through which new patterns of understanding emerge. There is a strong sense of personal discovery in some of the basic methods of working and learning in the discipline. For example, fieldwork is central to gathering information (knowledge about a problem): in fieldwork e/e scientists continually encounter new situations and have to embark on personal journeys of discovery. They have to continually invent (create) their own processes for learning to engage with new and emerging situations.

³ Keifer S (2005) 'Creativity and the perception of beauty: earth science thinking' Special Paper 'Earth and Mind.' Geol. Soc. America

Interpreting (imagining) past environments and events from geological evidence and from observations of contemporary environments from direct observation and physical evidence.

Interpretative mapping and modelling, especially under field, but also under laboratory conditions, both require substantial creative thinking and imaginative execution. You can compare a geological map at one end of the scale and a photomicrograph at the other end to a work of art. You have to interpret what the image is saying and different observers will have slightly differing interpretations all of which may be equally valid.'

Developing new theory and conceptualisations of how the earth works based on observation and measurement of natural processes. For example plate tectonic theory that integrates so many earth processes.

'I like to use the Werner v Hutton debate. The former's experience heavily influenced by ore deposition and recognition of the importance of water extrapolates this into a much grander and largely erroneous theory. Hutton influenced by the igneous rocks of Scotland extrapolates and gets closely to reality but underplays the influence of water. I do feel using 'historical geology' in an imaginative way can stimulate creative thinking in students.'

Designing processes to find out and develop and test theories – A designer is anyone who tries to improve or develop a product, strategy (process) and or theory. An overall goal of earth science is the designing of processes and improved theories to explain how the world works. One of the purposes of a higher education in earth and environmental science is to equip students with the capabilities to design their own processes for finding out how the world works. In geoscience education field mapping provides a good example of design in action and more generally the final year project/dissertation might be represented in terms of design.

Synthesis and connectivity – sense making in many aspects of geoscience education or applied practice involves piecing together (connecting) lots of disparate pieces of evidence (information) to construct a coherent and believable story/stories and/or to see emergent patterns of relationships. Capacities to synthesize complex and partial data sets in order to see and understand the whole requires both convergent (inductive) and divergent (deductive) thinking.

Thinking visually – there are many aspects of geoscience where complex relationships associated with dynamic (or what were once dynamic) phenomenon have to be represented and connected visually. The use of imagery to understand, explain and convey meaning engages the brain in creative thinking.

Doing things differently - e/e scientists are good at inventing new ways of looking at things. New technologies and techniques developed in allied disciplines (physics, chemistry, biology, and geography to name a few) are quickly adapted and used to gain new perspectives.

'Being 'Popperian' by inclination, testing ideas, and thinking of new ways of tackling old problems. Giving things a new look. Actually, I think earth scientists are rather poor at this, or rather, they tend to denigrate new ideas, demanding data and 'proof'. I don't mean Wegener's treatment here either. Astronomers and cosmologies publish all sorts of ideas for discussion; we don't tend to do this. There was an interesting article on this recently by van Loon in Earth Science Reviews (From speculation to model: the challenge of launching new ideas in the earth sciences)'

Language is an important expression of human creativity and the earth and environmental sciences have created their own symbolic language to enable knowledge and ideas to be communicated within the domain and to the wider public audiences. **Communicating ideas**, knowledge and deeper understandings are an important dimension of creativity. Earth and Environmental scientists are good at telling stories that explain how the world works/has worked in the past/ and might work in the future. **Story telling** is fundamentally about making sense of worlds past, present and future. It is profound curiosity that these worlds invoke that is the primary source of creative inspiration for many e/e scientists. Story telling as a way of theorising about the way the world works. Communicating complex information is enriched by the creative use of imagery (observational or manipulated imagery like that derived through Geographic Information Systems or Satellite Imagery), chemical, physical, numerical, graphical data, and the blending and integration of different sorts of information within a

narrative. There are two sorts of creativity here – the invention of data giving / communication techniques and their use to tell a particular scientific story.

Connecting and combining disparate pieces of information and ideas. Much of the information that e/e scientists work with is fragmentary and incomplete so they have to piece together (connect) lots of disparate pieces of evidence (information) to construct a coherent and believable story in order to see emergent patterns of relationships. Capacities to synthesize, combine and connect complex and partial data sets in order to see and understand the whole requires both convergent (inductive) and divergent (deductive) thinking. Allied to this perhaps is the capacity to connect, synthesize and develop concepts and ideas to help explain a given situation or evidence base.

Motivation for creativity

The complexity of the world studied by e/e scientists means that it is open to interpretation. Curiosity that drives the search for understanding is stimulated by the possibility space afforded by the possible interpretations of what is encountered (what emerges from study). The process of creating stories to explain the way the world works is one of generating possible interpretations and testing these through the evidence gathered. This reveals the interplay of divergent and convergent ways of thinking.

When invited to comment on the motivations for creative thinking and action, e/e scientists highlight the complexity of the world (past, present and future).

‘In one sense it is unknowable – there are so many factors, so much data that feed into to knowing and understanding. It requires people to engage in complex thinking and learning to partially understand how it works/has worked/or might work in the future. By definition, complex thinking in order to learn must engage all of our capacities for processing and imagining.’

‘There is so much ambiguity and paradox in the complex systems that we are studying that their recognition stimulates our curiosity. Many of the problems we work with have no single solution: the possibility space of different solutions stimulates creative thinking.’

‘The possibility for thinking imaginatively in our subjects is enormous. We are not so constrained as in the more analytically grounded sciences.’

‘There are lots of contexts/situations within the disciplinary territory that excite, interest, stimulate and capture the imaginations of teachers and students. The scale of what we work with from the nano-to the galactic from observations of how things happen as they happen to what happened 2.5 billion years ago. The awesome nature we can observe around us – volcanoes, hurricanes, earthquakes, tsunamis. The effects of what we do to our planet and [the planet’s effects] on our fellow human beings. Why we are here and how we got here.’

The intellectual and practical need to understand and explain this complexity stimulates curiosity and personal creativity and inspires teachers so that they can inspire their students.

From these sorts of responses it is clear that earth and environmental scientists have a sophisticated understanding of the idea of creativity and what it means to them in their discipline-based practice and also the way in which their curiosity and creativity is engaged and stimulated though the need to explain and understand the world they have created.

Is creativity essential to understanding in Earth or Environmental Science?

From the responses of earth and environmental scientists the core enterprises for understanding would appear to be directed to making sense of contemporary complex physical, chemical and biological (including human) systems. In the case of the environmental scientist this sense making is then used to predict the consequences of changes in the system (or make sense of possible future behaviours of the system). In the case of the earth scientist sense making is directed to interpreting geological records of the past and infusing these interpretations with knowledge of how contemporary complex earth systems work.

The responses of earth and environmental science teachers in this survey highlights the importance of an imagination that is able to assimilate and synthesise complex but often fragmentary knowledge from different sources and combine this with intuitive and more inductive ways of thinking.

Ways in which Earth/Environmental science teachers help/enable students to be creative?

'I feel that teaching can also be very creative - you have a certain content that you want to deliver, in terms of things students should know and be able to do at the end of the unit, but there are lots of options about delivering it. Even being able to phrase a question in two or three different ways to help a student work out for themselves how to do a stage in a practical, or keeping discussions going, involves an element of creativity. Using imagination to think about the needs of different learners in a group and develop activities that will help them all is creative. Working out how to get a certain core of key concepts across when your contact hours have been hacked and your class size increased DEFINITELY needs a lot of creativity - and to me seeing this sort of challenge as a creative activity helps me approach it more positively (after the initial 'this is impossible' rant of course), which makes it less stressful. It certainly takes creativity to work out why your wonderfully planned session fell completely flat, and to think of a different way to approach it in the future with minimum extra work!'

Teachers' conceptions of teaching are critical to any consideration of the promotion of students' creativity. Negative views of the idea that creativity can be taught are based on transmission models of teaching where teachers' attempt to transfer their own knowledge and sense making to students through lecture dominated teaching, where students' engagements in learning are predominantly based on information transfer, and are heavily prescribed and controlled by the teacher. Such conditions are less likely to foster students' creativity than models of the teacher as a stimulator, facilitator, resource provider, guide or coach, and where students are given the space and freedom to make decisions about their own learning process and outcomes, and where their reasoned arguments and solutions are valued.

Characteristics of teaching that is more likely to promote students' creativity in the earth and environmental science disciplines:

- Is open to the possibility of creativity.
- Provides opportunities for students to be creative and safe places where students can try out ideas.
- Lets students find their own way and make mistakes in the process.
- Engages students' through questioning and enquiry: poses questions in two or three different ways to help a student work out for themselves.
- Uses open ended (no right/wrong) answer type questions in assignments.
- encourages the search for more than one explanation or answer : e.g. give three possible explanations for this phenomenon / observation.
- Engages students for real understanding and encourages active participation at all levels and in all activities.
- Encourages learning through experience: particularly in situations that have not been encountered previously.
- Is democratic and collaborative (where teacher and students are co-participants in the process of learning).
- Repeatedly lays stress on the holistic interpretation of partial data: challenges students to think holistically.
- Utilises complex but incomplete data sets – to stimulate interpretative thinking.
- Shows how the environment is a resource for learning – including virtual environments.
- Shows that students themselves are a resource: encourages collaboration and cooperation.
- Encourages game play and simulation.
- Provides situations for learning that are relevant to the sorts of work done by earth and environmental scientists : authenticity as a stimulus for creative engagement.
- Involves them in designing things for themselves.

- Involve them in learning independently and taking control of their own learning.

To foster students' creativity teachers must:

- Give students permission to be creative.
- Be willing to take risks themselves – to create new experiences by doing things differently: doing the unexpected 'doing something a little wacky or playful'.
- Be flexible and adaptable to changing/emergent situations – by all means have a plan but adapt as events unfold and students' reactions emerge.
- Create the time and space for students to approach things in ways that will yield results are often in short supply.
- Respect and value students ideas and contributions and use these (rather than just their own ideas) to construct learning.
- Use real world events that provide powerful stories and imagery and give real meaning to phenomenon and capture imaginations - Adapting teaching and materials quickly to respond to real Earth events like major earthquakes, weather phenomenon. This captures students' interest in the subject and makes learning more relevant.
- Encourage resourcefulness – The environment is full of resources for learning. Teaching encourages earth and environmental science students to learn how to harness these resources. Field based learning situations in particular, with their physical challenges and inherent unpredictability require students to be resourceful and enterprising in order to learn.

Illustrative examples of teaching for creativity

'In setting assignments, it is important to make clear that students are not required to find the single 'right answer', because there is no single right answer. It also helps to make problems 'open-ended'. Encouraging creativity is easier at the start of a course, because the students don't have material on which to draw in order to come up with the answer. They then draw on their own resources and have a better chance of actually being creative. The above ideas have been put into practice in week one of a stage 1 module on 'The Global Environmental System'. The exercise, which I ran for the first time this September, is reproduced here.

Example Exercise A Model of the Global Environmental System

One of the aims of this module is that you should be "challenged to think holistically about the global environment". This means that you should have an overview of how the Earth operates as an integrated system. One way to achieve this is to develop for yourself a conceptual model of the system, which describes the different components of the system, how they are linked, and what is driving the dynamics of the system.

There is no single correct way to model the system and you are therefore encouraged to be creative in devising something that is meaningful for you. The exercise is therefore to outline your own personal model of the global environmental system, i.e. the bare bones of a model that will get increasingly complicated as you learn more about how it all works!

Bring the outline model with you to next week's seminar, in which this topic will be discussed. The outline models will be collected in and marked – they form part of the continuous assessment for this module.

Involvement in practical tasks – 'At lower levels, I find that practical tasks are the best way of prompting this sort of behaviour - thinking up ways of choosing between alternative answers, telling samples apart, requiring students to come up with at least three possible explanations for a pictured landscape feature or dataset... at second year, we get students to design their own dissertation project, which requires a lot of creativity on their parts - and a lot of patient coaxing and encouraging and guiding from staff - but can be very rewarding. Every practical set I teach has at least one 'open-ended' component, where there are several good answers and no perfect answer, to try and encourage this sort of activity. At third and fourth year there is more scope for creativity in discussions, as students have more confidence and are more familiar with each other and with the staff, they sort of have more belief in themselves.'

Experiential learning – ‘Traditionally, most geology graduates have to produce a geological map and dissertation as a focal part of their degree. This is a highly creative process. First, there is the map making itself based on observations made of outcrops in the field. Then there is the interpretation of this information in terms of a geological history, structural evolution and reconstruction of past environments. Visualising the map information in three (or four) dimensions and creating geological cross-sections is also part of the creative process. The independent mapping exercise requires the student to synthesize the knowledge and experiences from their degree course into the tangible entities of a map and geological report. The same could probably be said for all other Earth Science project work that involves the acquisition and interpretation of field data.’

Modelling and simulations – ‘These approaches could also include the use of modelling and simulation techniques for learning and assessment. One example of these approaches that we use is the introduction of Geographical Information Systems (GIS) into our Natural Resources Management curriculum. The use of GIS should allow students to organise, interpret and communicate environmental information in an efficient and effective manner. It will give students the opportunity to be creative in the spatial analysis of environmental problems.’

Playing games – ‘Part of our local philosophy ... is to maximise use of practical situations and simulations - we have recently developed a simulation/game called "Water for Walami" to provide a 'new and different' learning experience. The objective of the game is for participants to develop a strategic plan for supplying sufficient clean water for the island of Walami covering a 10 year period. The strategic plan is required to use an appropriate mix of possible solutions that have to be economically viable and environmentally acceptable.’

Designing web pages ‘Web Page Design for Pollution Science (Level 2): students are required to choose an anthropogenic pollutant and to determine the sources, chemical behaviour, effects on the environment, potential pathways and measures to minimise risk. Lectures and workshops cover theoretical concepts, but students are required to apply this knowledge to pollutants not covered in the lectures. All of this information is collated into a Web page design (using HTML format), suitable for a well informed lay person to access. Creativity is a key component of the assessment for the web page design.’

‘Consultant Report for a module on Contaminated Land (Level 4): the whole module is based around a derelict industrial site. Students complete a detailed site investigation for a chosen site in our area and have to write a summary report covering their investigative studies, a full risk assessment for any hazards they identify and recommendations for a clean-up strategy to complement their own chosen end-use for the site. As students have to design their own investigation strategies, collect their own data (+ pool it with their fellow students, interpret all information whilst undertaking a computer-aided risk assessment and finally recommend/design a practical end-use for the site, creative and innovative solutions can be encouraged by this essentially independent activity. Students learn a great deal more by this approach to learning and it probably makes them more employable if they develop competence in problem-solving skills.

‘Doing something a little wacky or playful can really help them unleash their creativity - very simple tools help. For example, in one first year practical on taxonomy, we classify Martians - I've made some bad sketches of cow-like animals with three eyes, odd numbers of legs and antennae, which have been scanned in, coloured and printed out on fine card, then laminated.

Recognizing and assessing creativity in earth and environmental science education

The views of earth and environmental science teachers fall into two camps. Some teachers believe that students' creativity is evaluated through explicit assessment criteria. Others believe that insufficient attention is given to recognising students' creativity and that at best the evaluation and recognition is implicit. Unlike respondents in some other subjects, none of the earth science respondents highlighted that creativity is more likely to be associated with the highest levels of academic performance.

'We rarely make assessment of creativity an explicit objective. Although most of us would perhaps claim 'we know it when we see it'. 'I don't think I explicitly assess creativity! It probably is blended into other learning criteria. I don't think it can be easily assessed.'

'I don't think I explicitly assess creativity! It probably is blended into other learning criteria. I don't think it can be easily assessed?'

'I believe students should be allowed to make mistakes in creative assignments, provided they learn from their mistakes. It is important for staff to recognise that students are taking some elements of risk in undertaking creative work, and the students should be rewarded accordingly if they can rationalise the risk.'

'Time-limited unseen assessment items are, in my view, less preferable than coursework items when assessing creativity.'

'The aspect of creativity that can be assessed more readily is the actual output as measured against defined criteria - however, the unseen hours of effort in getting there cannot be assessed readily. For example, a solution that involves an aspect of design may come more readily to one student than another and one may take half the time of another to achieve the same output - although two completely different amounts of effort have been expended on the problem.'

'It is difficult to assess in most cases (we don't try hard enough though). As assessment rules the forms of assessment tend to be traditional and 'safe' (a form of the test papers in '1066 and all that' comes to mind: 'explain how plate tectonics works – be creative'). Bloom however, does not always help, at least in exam question setting. Nevertheless there are ways Bloom can be brought in, via learning styles; see eg. LeFever, 1985, 'Creative teaching methods' Things like PBL and dissertations certainly help.'

'I think that it will be necessary to devise an assessment scheme that ranks according to the degree of novelty from 'tried and tested solutions' (textbook answer) at one end to 'completely novel' at the other.'

'I have to admit that for the exercise described above (A Model of the Global Environmental System) I did not have a planned assessment scheme or criteria to evaluate creativity. I simply identified what appeared to be creative elements and awarded additional marks accordingly.'

Where creativity is assessed it is focused on the product (e.g. map, report, presentation, web page) but there is recognition that it is also important to evaluate and reward the creative process. Creativity is a process which may or may not result in a product. Evaluation therefore has to understand from an individual student's perspective the process he / she has gone through. This would require students to make claims (supported by evidence) of their own creative process and require them to engage in reflective thinking.

'It is important to recognise that the 'product' could be wide-ranging in a creative work (e.g. the GIS work outlined above). Thus, it may be difficult to devise a fair grading scheme for the actual 'product'. The justification for the product of an assessment, the process of arriving at the product, and the recommendation for future work become more important than the product itself. It may be better and fairer to put more weight on the grade for the process and the reflection on the process.

There is also recognition that to be creative students must take risks, and sometimes risk taking means that students will not accomplish what they are seeking to accomplish. Assessment must therefore be willing to recognize and tolerate failure to achieve the objectives for the task. Outcomes based models of assessment assume that we can predict what will emerge : where creativity is concerned we don't know what will emerge.

'We tend to play safe where assessment is concerned. But, if being creative involves taking risk then students must be permitted to not succeed in what they were trying to do. Our assessment methodologies and criteria generally see this as failure.'

'The evidence for creativity provided in summative assessment is primarily in the stories students' tell – the way arguments are constructed and connected, the way they respond to new materials/ideas/data they have not previously encountered, the range of explanations/possibilities they offer, the way ideas are used and connected and the transfer of ideas from one context to another.'

Some aspects of creativity are more difficult to assess than others. For example, assessing the creativity of a student who is a bad communicator. Subtle forms of synthesis and originality, and individual creative contributions in a group. Aspects that are easier to evaluate include: synthesis of ideas from different modules, developing a range of explanations and the visual presentation of data in an unexpected and effective way.

Examples of evidence used to evaluate student's creativity includes

- Written arguments: bringing ideas together: connecting information
- Evidence of using a range of hypotheses
- Justification of solutions both in the reports and presentations
- Use of material that differs from what was given to the students : material that is different or unusual (of course this is affected by our own limited knowledge
- Doing something 'different' to what has been done before that meets the solution in either a more economical way than others, or on the basis of other established criteria, can be more fully justified - such as less environmental impact against set CBA measures.
- Innovative' presentation of data
- Doing something different and rationalising it e.g. application of known theory in a different way; different interpretation of a model that is still valid and can be fully justified.

'What we are looking at is a situation whereby the average student with the knowledge they had prior to the 'assessment' of their creativity has come up with something unexpected for the expected level of knowledge and its application to the problem they faced.'

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