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Social creativity at the coalface: a heuristic case study incorporating non-human agency

Abstract:

The safe operation of an underground coal mine is coordinated in a control room where data from a range of sensory equipment, and indeed, all communication between underground personnel and the surface, is monitored. It is here that response to any emergency is initiated. Specific hazard management plans and emergency procedures will be triggered by any one of a number of automatic or manual alarms. The complex array of information to be processed has the potential to overwhelm the cognitive capacity of the control room operator, particularly in a potentially catastrophic emergency scenario. A proprietary computer software-based system (Nexsys™) uses a rules engine to assist with real time monitoring and response affording control via a single interface. This paper arises from the experience of a designer charged with proposing a user interface design at a specific site, enabling efficient monitoring of prevalent operational conditions and prioritised, context-relevant access to technical documents, procedures and communications. It is a reflective case study account that draws on trans-disciplinary literature in order to theorise the nature of the creativity involved in implementing a user centered design approach. The heuristic analysis, from the perspective of a creative industry practitioner working in an industrial situation not commonly associated with creativity, proposes that Csikszentmihalyi's (1999) "systems perspective for the study of creativity" be appended to include non-human agency before a convincing account of the sources of creativity involved may be proposed.

Biographical note:

Dr Ashley Holmes came to academia following a successful twenty five-year business career as a creative industry producer and company director. He is an interaction designer and has gained international recognition as a new media digital artist. He currently lectures across multimedia and communication programs at CQUniversity Australia. His current research interests include transfer of tacit vocational knowledge, virtual collaboration, approaches to creative practice and web ontology for art.

Keywords:

creativity – non-human agency – interface design – mining hazard management

A creator is not a being that works for pleasure;
a creator does nothing but that which [s]he needs to do.
Deleuze (2001: 102)

Introduction

When an apt search is addressed to that mega-meta archive of remediated moments, *YouTube*, it will yield multifarious versions of a debate that took place in 1971 on a Dutch TV channel between the celebrated philosophers, Michel Foucault and Noam Chomsky[1]. The topic was *Human nature: justice versus power*. In response to a question about his ideas on innate human qualities Chomsky refers to our use of language as 'highly creative'. It is not random novel behavior; it is one of the innate organising principles that guide social, and intellectual and individual behavior, he says. Foucault retorts that the notion of 'life' itself is not a scientific concept, rather an epistemological indicator, somewhat like the notion of 'human nature'. He says that these are neither innate nor learned but rather institutionalised practices and so involve relations of power. The first part of this conversation is most interesting in relation to the topical discussion of 'creativity' because, between them, the interlocutors draw out theoretical dimensions that complement the pragmatic account Robinson provides in *Out of our minds* (2011), with his focus on innovation and the role of creativity in education. Their apparently contrary assertions regarding creativity also have bearing on the main discussion in this paper about the social nature of creativity – albeit, somewhat extending the common understanding of 'society'. So please abide some further brief indulgence of this philosophical theory. Its contextual relevance will be explained as the author recounts his experience being consulted as user interface designer for a hazardous environment information technology project.

Chomsky explains that his use of creativity is not the value-laden sense equated with innovation but emphasizes that creativity is a 'normal human act' somewhat akin to Descartes' 'common sense'. However he poses the possibility of another form of creativity that goes beyond the normal and which 'may not exist fully developed in the mass of mankind, and may not constitute part of the normal creativity of everyday life.' He moves to distinguish between 'low level' creativity innate in individuals and a transcendent form arising from disciplines in science and art.

> If we really want to develop a theory of scientific creation, or for that matter artistic creation, I think we have to focus attention precisely on that set of conditions that, on the one hand, delimits and restricts the scope of our possible knowledge, while at the same time permitting the inductive leap to complicated systems of knowledge on the basis of a small amount of data. That, it seems to me, would be the way to progress towards a theory of scientific creativity, or in fact towards any question of epistemology (Chomsky: Chomsky & Foucault 1971).

Foucault will not have a bar of this! He appears not to warrant *either* notion of creativity. Rather than acknowledging that a body of knowledge grows through creative insight, he thinks in terms of transformation. 'I would much rather say that there are many different ways of making possible simultaneously a few types of

knowledge' he says, and that knowledge is discovered and rewritten according to socio-political, technological and economic determinisms.

> There is, … from a certain point of view, always an excess of data in relation to possible systems in a given period, which causes them to be experienced within their boundaries, even in their deficiency, which means that one fails to realise their creativity

Foucault emphasizes, 'what is striking is the proliferation of possibilities by divergences' (Foucault: Chomsky & Foucault 1971).

Recalling this infamous debate art historian/philosopher John Rajchman says that the protagonists give rise to a 'new question about non-normal discursive novelty.' He says the whole problem of creativity shifts accordingly. 'How (and in what conditions) can one 'cross the line' of discursive 'regularities' governing our talk and say something 'new'?' he asks (Rajchman 2008: 86). This paper seeks to address his question.

That the Chomsky-Foucault debate is founded on each philosopher's portrayal of the structural origin and discursive function of language is significant to notions that will be explored in this paper particularly in relation to the development of technical documentation and software solutions in relation to risk in hazardous environments. With reference to the observations of an expert in such technical documentation (Sauer 2003) it will be demonstrated how tacit 'pit sense', scientific knowledge and technical know-how are networked, transmitted and assembled in a constantly changing body of rhetoric. Shaping the constitution of it are socially and culturally institutionalised restricting and restraining conditions but also entrustments and other enabling factors.

This paper is a hermeneutic case study of one short cycle in the iterative development of a temporally emergent technological system being developed for use in underground coalmines that utilises this pool of knowledge. It is an unapologetically reflective study from the point of view of an outsider to the cultural domain of hazard management and the field of mining, with no prior knowledge or experience of the core business – a user interface design specialist who is also an academic with an interest in creativity and it manifestations. The discussion will concur with Robinson (2011) and Csikszentmihalyi (1999) that there are societal and cultural environment factors as well as qualities and characteristics attributable to individuals playing a part in enabling conditions for creativity to flourish. Then, a potentially more controversial suggestion will be made: That Csikszentmihalyi's 'systems view of creativity' – which features culture, society and personal background, incorporating the domain, the field and the individual respectively in the transmission of knowledge and the production of and selection of novelty – appears to be missing one vital contributing sector. The missing part is the *milieu,* which when added, enables the contribution of non-human 'agency' to the creative process to be recognised. It is important to indicate that the term 'milieu' is used here as a synonym for 'environment' in a broad sense that is intended to enable consideration of non-human actants, and *not* in the strictly social sense that Csikszentmihalyi uses where he says, 'it is possible to single out seven major elements in the social milieu that help make creative contributions

possible: training, expectations, resources, recognition, hope, opportunity, and reward' (1996: 330).

Context

In 2011, collaboration between an information technology (IT) system development firm and a small multidisciplinary team of academic 'experts' was made possible through a *Researchers in business* grant, under the Enterprise Connect initiative of the Australian Commonwealth Government. The IT firm had previously been involved in the pilot commercialisation of a real-time risk management system for underground coal mines originally developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) called Nexsys™. The firm had secured a license for the technology and a contract to perform further implementation trials in three underground coalmines operated by an international energy company. Essentially the collaboration involved customisation of the Nexsys™ rules engine and user interface to suit site-specific conditions, procedural and requirement variables, as a further phase of pilot trial for the system. The academic team consisted of an IT systems consultant, an information systems (IS) developer, and a user interface (UI) designer [the author of this paper]. No members of the academic team had prior experience working with mining. They collaborated with three members of the IT firm: an executive director and a project manager, both with extensive knowledge of coal mining and systems development, and a contracting programmer/developer familiar with the Nexsys™ system. Arrangements with the client-side stakeholders and – particularly relevant for the UI designer – a group of four control room operators (CROs), were brokered through the mine operator's director of health and safety via the project manager.

The Nexsys™ system has been designed to help address the problem of complexity in management of risk in underground coalmines. It enables data integration between systems of process control and monitoring, site safety systems, human resources databases, and tracking technologies. It takes account of site-specific hazard management plans and prescribed procedural responses and delivers context relative, prioritised information, related instructions and communications templates in response to scenarios as they unfold in time. The system can also be used to actively predict and so help prevent potentially catastrophic events. The control room is not only the hub for all communication and traffic between surface and underground but also the primary monitoring station for all data to do with process control and hazardous risk management and, in the event of an emergency, the emergency response control center. The purpose of this project was to develop the Nexsys™ system at specific sites in order to further 'research the requirements to integrate electronic, manual and historic data acquisition systems and produce a software package to be located in the mine's control room.' The software should have a singular database containing all the mine's data requirements to monitor principal hazards (Enterprise Connect 2011).

Complexity in the control room

Presently the data that Nexsys™ portends to be able to manage is available from discreet systems in various textual and visualisation formats across a number of

Fig. 1. This scene depicting a control room visited by the author for site reconnaissance and user interviews has been intentionally blurred to obscure detail.

screens. In the case illustrated (see, figure 1, above) each computer screen is connected to a separate processor and each had its own mouse and keyboard. The CRO is coping with a huge amount of data from sensors presented in this fashion and it is being refreshed every few seconds. The potential for information overload is ever-present. If the CRO does not perform his duties appropriately the danger to personnel safety and risk to plant with associated costly productive downtime is immense. In addition, the CRO is responsible for maintaining documentary records of events to meet regulatory requirements.

With its predictive capability, using rules-based prioritisation and context-based presentation of information and communication options, Nexsys™ can present the most relevant information for the CRO to manage on one screen. Designing the structure and function of this screen for the specific conditions and requirements of the mine operations became the task of the author. Essentially, the UI designer was challenged to interface the extant hazard management plans and procedures with an innovative information technology system to be trialed for a specific user group.

Subsequent to a review of relevant literature, this paper will first outline the UI design process undertaken by the author, sketch the key features of the solution proposed, and then note the stakeholders' key initial responses. Then, in reflective mode, a brief detour through further literature on material agency will preface the second part of the paper where this single instance of an iterative cycle of hazard management systems development will be analysed using Csikszentmihalyi's systems perspective for the study of creativity as a starting point.

Contextual literature

Beverly Sauer's *The rhetoric of risk* won a publishing award for Best book in scientific and technical writing in 2003. Based on research conducted in the US, UK and South African underground mining operations, she describes how regulatory safety standards arise from accident investigations and statistical reports that feed into policy and regulation. These inform practices and procedures, training and instruction and local documentation. She describes this as an ongoing, iterative cycle (76).

In Australia mining tenements are issued by the states and relevant legislation and regulation is the jurisdiction of each State. In Queensland,

> a coal mine's safety and health management system must provide for the following basic elements –
>
> (a) risk identification and assessment;
>
> (b) hazard analysis;
>
> (c) hazard management and control;
>
> (d) reporting and recording relevant safety and health information and data (Queensland Coal Mining 2001: 6).

Hopkins and Wilkinson (2005) outline how in Australia, a National Mine Safety Framework Implementation Plan has been endorsed that strengthens an emphasis on duty of care extending all the way through the chain of supply and importantly including the mine owners. The resulting 1999 Queensland Act represents "the most advanced thinking in the mining industry" because it insists that principal hazards be defined requiring mine operators to develop Principal Hazard Management Plans (PHMPs). The plans use regulatory standards to identify indicatory factors of increased risk and for each 'trigger event' an action response plan is specified. These are known as Trigger Action Response Plans (TARPs). However, as Sauer points out,

> The problem of risk thus challenges conventional rhetorical notions of instruction and procedures as a generalizable set of practices and procedures that can be formulated prior to an understanding of material conditions in local environments. (182)

Australian Occupational Health and Safety expert, Neil Gunningham, claims that even in states with more progressive and potentially more effective regulation, such as Queensland and New South Wales (2007: 5-7), there are still 'substantial challenges' along the road to the 'zero harm' objective (2006: 16).

In 2010, research commissioned by the Australian Coal Association Research Program (ACARP) focused on the control room as the site where critical information must be available during an incident that may be triggered by any one of the regulatory indicators, or indeed, by un-prescribed circumstances. This is especially so because, in the early stages of response, before senior mine officials can assume control, critical communications and emergency responses are also coordinated from the control room. Principal findings of this research project were:

- The emergency management system (EMS) often seemed to be no more than a paper document that had not been properly tested.

- Most mines had not formally identified what information would be necessary in an emergency: esp. what would be required to ensure rapid re-entry for rescue purposes.
- There is an urgent need to define the minimum information requirements.
- There is a need to define an industry wide competency for control room operators (CRO).
- Mines need to significantly increase training carried out for emergency preparedness and response especially in the management of incidents (Cliff & Grieves 2010).

A paper presented at the 2011 Underground Coal Operators' Conference further outlines the history of the development and trialing of the Nexsys™ system up to the point where the author became involved (Haustein et al 2011).

Interestingly Sauer, in her rhetorical analysis of technical documentation, makes no reference to Foucault and his focus on discourses as 'practices that systematically form the objects of which they speak' (1971: 48). She does however give credence to Bruno Latour and other authors from the social studies of science and technology. Talking about how accident reports and investigations contribute to standards and how standards 'blur the distinction between 'expert' science and lay understanding,' she notes how, according to Latour, Woolgar and Salk, 'the material world becomes invisible in the traces and inscriptions that become scientific fact [*Laboratory Life*, 1986]' (37). What Sauer describes is a process that is also congruent with a notion arising from the theory of distributed cognition which recognises that the participatory interactive construction of knowledge is product of neither individual nor organisation (Taylor & Van Every 2000: 3). Expertise, according to Sauer, 'is context dependent and highly situated' and the accumulated knowledge is distributed throughout the entire cycle. She warns:

> Distinctions between expert knowledge (based in science), local knowledge (the property of interested citizens), and experience (tacit or craft knowledge) may … obscure the degree to which writers draw on many different types of expertise at different moments within the Cycle (78-79).

Sauer identifies that the technical documentation cycle involves three types of warrants, each grounded in embodied sensory experience:

- Pit sense (embodied sensory knowledge) – direct physical sensations and observations in highly specific local environments
- Engineering experience (material history) – signs or indices embodied in objects and materials, recorded at sites
- Scientific (invisible) knowledge – written, sensed or perceived as data (182).

Sounding somewhat Foucaultian, Sauer says,

> …the knowledge needed to manage hazards is a collaborative enterprise that must be constantly updated and recovered through the processes of transformation and documentation...

Further, she says, that:

> When agencies document information, they attempt to stabilize information for the record. But the cumulative body of documentation in an industry is constantly in flux as individuals continue to create new knowledge of the environments they seek to regulate (67).

Whilst there is this concept of flux, there is an accompanying sedimentation. 'As these rhetorical properties achieve stability over time, documents become templates for particular kinds of activities'. She warns, 'Over time, this stability can create problems if documentation does not change to meet current needs' (73). Emphasising the difficulty that regulators and the developers of hazard management plans and procedural responses and rules face Sauer writes:

> In risky environments, events and conditions change rapidly. To manage risk, management and workers must observe, evaluate, and interpret rapidly changing sensory information in the environment. Safety engineers can prepare a general plan, but local conditions ultimately define when and how individuals manage risk in local sites. The problem of risk thus challenges conventional rhetorical notions of instruction and procedures as a generalizable set of practices and procedures that can be formulated prior to an understanding of material conditions in local environments (182).

These observations may convey to the reader some understanding of the challenges that the team involved in the pilot implementation of Nexsys™ would encounter.

Design process: Control Room Operator focus

Given that there is ample literature on the topic[2] there is neither the need nor the space here to rehearse the principles behind the user-centered design (UCD) approach. There had been an interface design prepared for an earlier trial (Haustein et al 2011) but the UI designer was directed not to consider it and to start from scratch. The designer was totally focused on working from the CRO user end, and deciding how to present the situational data, procedural instruction, and communication utility most relevant to the CRO at any time with consistency, regardless of the type of event that the system of alarm prioritisation may deliver. Because the UI designer was neither briefed (beyond basics) nor had prior knowledge of the system architecture of Nexsys™, the designer was never in a position of trying to modify the CRO's behaviour match the system capability[3].

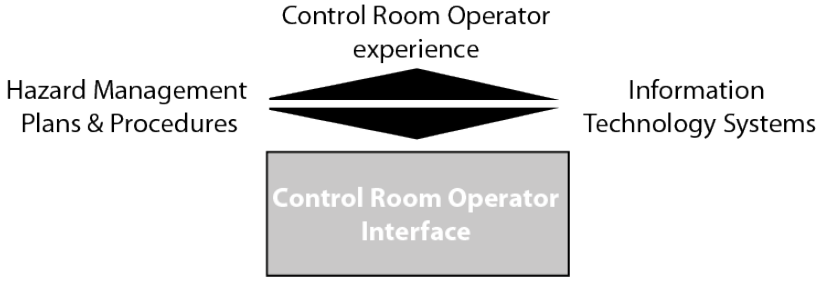

Fig. 2. Focus on usability from CRO point of view.

Specific design considerations

For the purpose of the Phase 1 demonstration that the UI designer was involved in, five Principal PHMPs were chosen: Spontaneous Combustion (Spont Com), Ventilation (Fans), Gas, Emergency Response, and Strata. However, as things turned out, for the purpose of demonstrating the UI design concept, not all of these were required to be visualised in step-by-step detail.

The design solution

Key new concepts in response to the brief were recommended at the early 'sketch' phase of interpretation (see Figure 3).

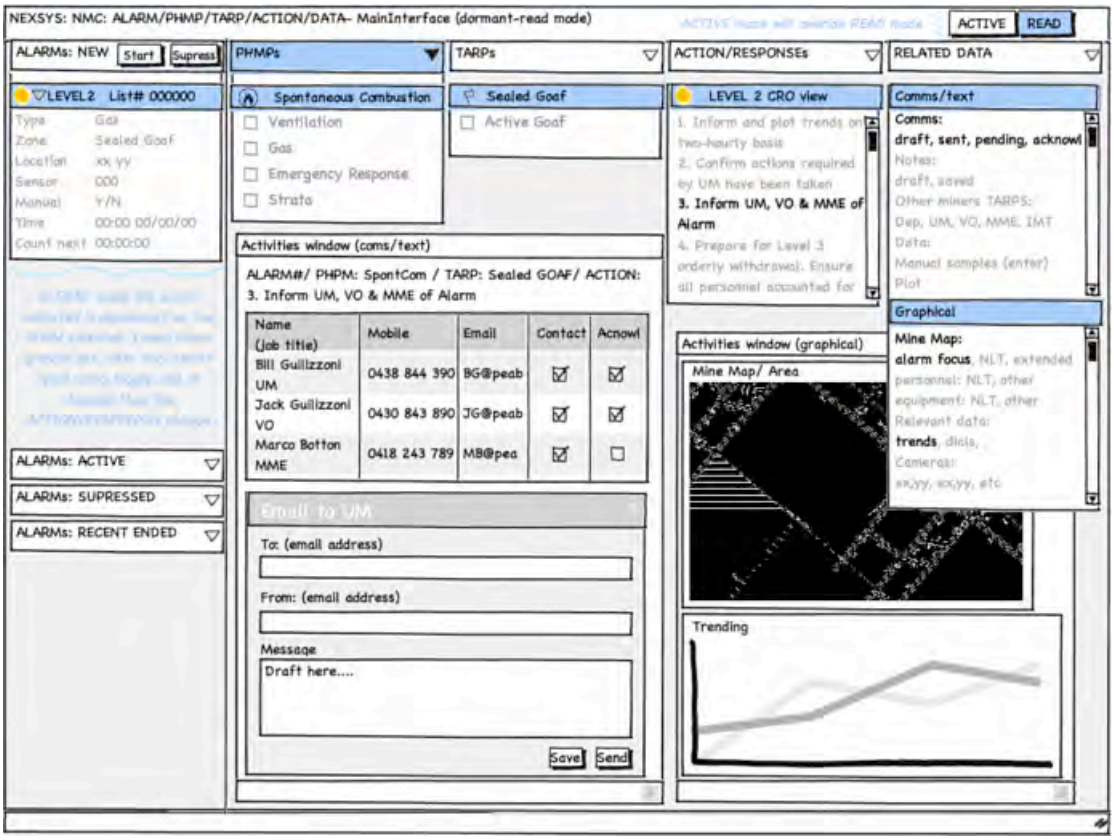

Fig. 3. The *wireframe* design stage (simple conceptual outlines) focuses on organising usability from CRO point of view.

The screen is divided into five columns, to be read from left to right, reflecting the procedural hierarchy: Alarms, PHMPs, TARPs, Actions/Responses, and Related Data. Floating over are two panels that provide context sensitive functionality: one for texts and communications and the other for data visualisations, real-time imaging etc. Using the Communications window a CRO can send information to other participants in actioning the TARP. Communication can be sent to email or Cap Lamp. If communications are performed verbally, comments can be entered within the communications box. Acknowledgement (tick) boxes allow the control room operator to quickly mark off completed tasks. This information is stored in an audit log that records all the information for the alarm for further investigation and reporting. The

CRO stakeholders enthusiastically received this feature. There was also the suggestion for a 'Read' mode where an alarm could be selected, its level manually adjusted and the associated management plan and response procedures could be followed and rehearsed. This value of this new feature for training was immediately recognised by all stakeholders.

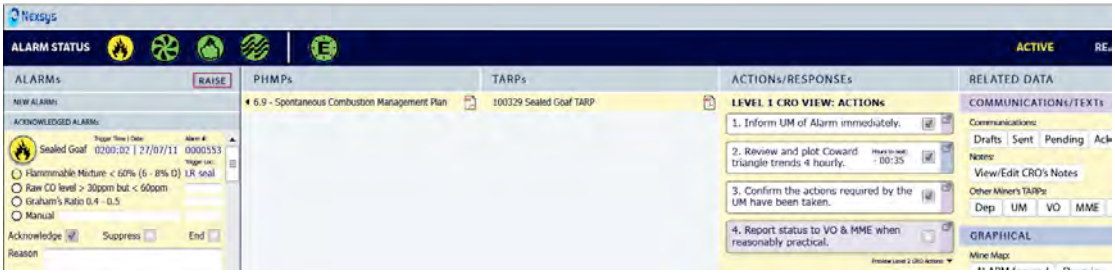

Fig. 4. The *hierarchical task analysis* revealed that even though 'Emergency Response' had been classified as a 'PHMP' in the brief, it was actually a 'Manual' – quite a different category of procedural document. This *discovery* prompted a structural change in the interface design reflected in the distribution of icons at the head of the interface.

In the second iteration of the design concept, the interface displayed icons for each type of alarm at the head. Each icon changes colour to match its state according to prescribed levels, so a CRO can see at a glance the status of the system (see Figure 4).

Further outcomes

At the outset the designer was completely unfamiliar with the procedural documentation: the PHPMs, the TARPS, and other manuals. As part of the task analysis it was necessary for the designer read these line-by-line, step-by-step, from the point of view of the CRO having to respond and follow instruction. Some logical inconsistencies, procedural gaps and miss-matches became apparent. This indicated that the texts, prepared asynchronously by segmented and discrete fields of practice, contributing to hazard and emergency management procedures and plans in independent cycles, are often untested as a compiled flow of function, echoing in particular the first two findings of Cliff and Grieves (2010). It is also an indication of the sedimentation that Sauer asserts can occur in the rhetorical cycle. That the anomalies were highlighted and reported serves to highlight the value of an outsider's point-of-view in the overall iterative process of system development, thus reinforcing the potential that the *Researcher in Business* program provides for social creative input. In addition, the designer's input contributed to rules engine application development. For instance, it became evident that the capability to de-escalate an alarm sequence due to a reversal of conditions had not previously been considered. The designer had visualised such capability, simply assuming the system could do it.

Accounting for creativity

Considering the foregoing, mightn't it be easy to portray this engagement simply in terms of a successful outcome resulting from the deployment of a creative specialist to solve a problem? Any veracious account should also consider:

- the temporal and locational, emergent nature of the IS development means that the project is yet incomplete and likely to be ongoing for some period of time;
- the collaborative nature of the development involves a host of players not least of which (besides teams of people: experts, managers, miners, CROs, IS/IT developers) are the Nexsys™ software and related sensory apparatus and information technology systems that feed into it;
- the institutional ordinances that govern and regulate mining operations, and the agents that collate accident and incident documentation; and,
- the conglomerate material environment which the engineers and the miners engage with, and which a complex array of sensors monitors and responds to.

The outline of the development of risk management regulation and its application in Australian underground coal mines presented in the literature review above would appear to have little to do with creativity. And how might Foucault's focus on the discursive nature of the knowledge framework from which the production of rules and regulations arises account for creativity? In the already cited interview he says, 'understanding modifies itself in its formative rules, without passing through an original *inventor* discovering the *truth.*' Accordingly, even the technically innovative Nexsys™, with its system for data integration, reigning in complexity, and prioritising risks, might be better characterised in terms of 'transformations of totalities' – rather than a creative idea 'brought to light by individuals'. It is not intended for this paper to characterise Foucault as the 'Scrooge who resents creativity,' but (taking some liberty with that Dickensian metaphor) further 'apparitions' of creativity are yet to be evoked as this paper leads from the past to present and beyond, investigating themes of creativity and material agency.

This author has remarked elsewhere a cynicism for the propensity of creative industries researchers to search out and document evidence of creative input/output throughout ever widening frames of reference (Holmes 2009). Whilst in one sense this endeavor may rationalise the economic contributions of creativity to gross national product, the logical extent of such an account of creativity would not necessarily be accomplished even when the 'common creativity' that Chomsky acknowledges is accounted for. After all, in that portrayal, even everyday conversation is considered creative. Though we are all richer for such fundamentally creative experiences, it is hard to account for how the country is!

Material agency

The creative industries endeavor appears to stop well short of acknowledging the wholly universal nature of creativity such as sketched by philosophers Deleuze and Guattari and expounded by Australian, Elizabeth Grosz in her 2008 text, *Chaos, Territory, Art*. By this account creativity is the manifesting of matter and energy from cosmological chaos. It is witnessed in the formation of galaxies and stellar systems, in the vibrations of subatomic entities, in cellular and network structures: indeed, throughout material existence. It is affirmed in evolution and especially evidenced in sexual selection. Various 'planes' of human and non-human activity are

acknowledged: 'technical, material, organizational, administrative.' The roles of artists, philosophers and scientists are particularly valorized. These are agents who

> slow down chaos enough to extract from it … [a] mutually referential field of interacting artworks, concepts and experiments … not to order or control chaos but to contain some of its fragments in some small space (a discourse, a work of art, an experiment), to reduce it to some form that the living can utilize without being completely overwhelmed (3, 26-8).

Though encompassing broadly the human and non-human here Grosz, like Chomsky, appears to endorse the transcendence of certain 'genius' individuals and their abilities. She apparently focuses on the creative aspects of knowledge production—that is, epistemology, with somewhat heroic overtones. To encounter and more wholly consider *other-than-human* agency some further literature review is in order. Interestingly, with regard to the focus of this paper, much of it arises from sociology of technology contexts.

Here we find various visions of material agency proposed, dependent on philosophical grounds somewhat to do with how causality is accounted for in worldview (Bijker 1995: 288). The range of opinions to be summonsed in what follows is by no means comprehensive. Perhaps consider them as ephemeral tints in a spectrum. Towards one end there is a soft or weak kind of agency such as *affordance* (Gibson 1977, Norman 1988) – where an object may invite a subject to perceive its potential function. In the opinion of this author this kind of 'availability' of an object may be considered an extension of the gestalt of an object, derived from its form. Further along the scale there are notions such as Orlikowski's 'material performativity' (2005: 185). Orlikowski has been influenced by Giddens' structuration theory and for her the agency of technology arises from practices that are structurally embedded in it. Suchman, who researched computational interactivity at PARC in the 1980s, apparently formerly shared this view but has more recently described how her position on material agency has shifted over the years. She now thinks 'agency – and associated accountabilities – reside neither in us or in our artifacts, but in our intra-actions' (2008). Around about the middle of this spectrum there are accounts like Pickering's 'constitutive intertwining and reciprocal interdefinition of human and material agency' (1995, 26). His studies in sociology of science and technology, led him to postulate that agency in the natural world and in technology presents itself as resistance to and accommodation of human intentionality. The creativity that results from a scientist having to rethink and retune their quest is evoked in Pickering's metaphor of the 'dance of agency'. Information system theorists Rose and Jones take up this theme in a more recent discussion of the 'problem of agency' where they conclude that both machines and humans have 'capacity to make a difference' (2005). Most authors mentioned above acknowledge the work of Callon and Latour and the renowned actor network theory (ANT), as influential in the establishment of theories that account for material agency. Kirchhoff (2009: 1.1), citing Latour (1999: 178-80) succinctly summarises what distinguishes the hard or strong zone of the spectrum of ideas on material agency pointing out that: 'the roles that humans and non-humans play in networks are *functionally equivalent*.'

The task of further theorising what De Landa (2002) in a reading of Deleuze texts describes as 'flat ontology' (58), 'avoiding essentialist and typological thinking in all realms of reality' (40), has more recently been taken up by a number of philosophers under the umbrella term, *object oriented ontology,* also known as *speculative realism* (Bogost 2012, Bryant 2011, Bryant, Harman & Srnicek 2011, Harman 2002). Loosely described, elements of this theory body relevant to the discussion (though the proponents are by no means in agreement about the philosophical details) are: dissolution of mind-body separation and subject-object duality; rejection of the privileging of human existence over the existence of all other things (because humans exist on an equal footing with all things); an emphasis on relations between things without causational reduction (that is, without accounts of things being reduced to fundamental causes); objects are irreducible to one another even though they are usually conglomerations or made up of networks or associations; the closed systemic nature of objects accounts for their inaccessibility to each other except through negotiated endo-relations (networks).

Ethico-political implications arise from philosophical acceptance of material agency (Bennett 2009). Bennett cites De Landa[4] in championing that '…inorganic matter is much more variable and creative than we ever imagined. And this insight into matter's inherent creativity needs to be fully incorporated into our new materialist philosophies' (7). She is a strong advocate for the creative input of things into human affairs:

> The association of matter with passivity still haunts us today, I think, weakening our discernment of the force of things. But it might be only a small step from the creative agency of a vital force to a materiality conceived as itself this creative agent (157).

Creativity under ground

Whilst portending, as its title suggests, a compendium of accounts of creativity, the *Handbook of Creativity* completely overlooks the themes that most of the aforementioned visions of material agency might suggest. Its focus, as determined by the majority of contributions, is on novelty and value, most often described as 'some form of utility - usefulness, appropriateness, or social value' (Mayer 1999: 450). In spite of the 22 articles covering research from a wide range of fields, it seems a consensus on the real or actual nature of creativity is elusive. There is one chapter however that provides a potentially suitable framework for analysis of creativity in the case of the topical Nexsys™ implementation trial because it accounts for the integration of systems in the construction of knowledge. Csikszentmihalyi (1999) claims that under certain conducive conditions creativity may arise from the interactivity between individual, society and culture, but that to distinguish between originality and creativity, the latter is made manifest only with respect to the values of the community. Csikszentmihalyi recommends in his 'systems model of creativity' that we consider the environment in which the individual operates. In relation to the individual there are two further salient aspects: 'a cultural or symbolic aspect' which he calls 'the domain', and a social aspect: 'the field'. Following the logic of this concept, the domain is a necessary requirement because no new ideas form in a

vacuum. ‘‘New’ is meaningful only in reference to the ‘old’’. There is always an existing cultural framework: ‘objects, rules, representations or notations’ (314).

> For creativity to occur, a set of rules and practices must be transmitted from the domain to the individual. The individual must then produce a novel variation in the content of the domain. The variation then must be selected by the field for inclusion in the domain (315).

When considered in conjunction with the postulation from distributed cognition theory about participatory construction, where knowledge is collectively synthesized and transcends the individual, this is an appropriate model for analysing this case. However, in order to take account of material agency in any of the guises recognized in the above-cited literature, an enhancement of Csikszentmihalyi’s model (315) is proposed (see, figure 5). In this model the concept of society is expanded. Non-human

Fig. 5. Csikszentmihalyi’s diagram visualising the relationships involved in his ‘systems view of creativity’[6] has been adapted to show how the designer, informed by the rules of the hazard management domain and in consultation with mine safety stakeholders (principally the CROs), produced solutions for the system which would not close the creativity loop unless culturally accepted. However, after Latour and his followers, in this adaptation the non-human participants in the milieu are also actants in the social system that generates creative outputs.

elements are considered under the umbrella term, ‘milieu’. Included are actants at the weak end of the material agency spectrum: the affordances and the material performativity incorporated in the IT systems. Also included are processes and technologies where human and material agencies are intertwined. Indeed, according to theories aligned with *Object Oriented Ontology*, all things that influence the workplace at the coalface must be considered because humans and things are on the same ontological level. When conceived in this way non-human agency may be accounted for in the cycle of creativity involving knowledge translation and the

application of the technological system along with the factors and conditions that Csikszentmihalyi identified.

Reflecting on collaborative experience of iterative development of the emergent Nexsys™ technological project, and seeking to account for the human and non-human creativity involved, the author is confronted with an immense array of inputs. To mention them all would read like an extremely long 'Latour Litany'[5]. The inputs are the product of countless agents of contributors to what Sauer (2003) eloquently summarises as: embodied sensory knowledge, material history, and invisible scientific knowledge. The compelling literature on material agency suggests many more agents. Opinions from the weak end of the spectrum suggest that, at least, all of the mine technology (from the IT systems to hydraulic jacks at the longwall, to the mine ventilation system) must be considered. Opinions from the strong end of opinion on material agency claim the very elements in the geology and the underground atmosphere and the forces they generate in association must be too. An interesting thing about an underground mine environment is that, for the sake of hazard management, many of these things are monitored and the data from their inputs recorded and processed, and so they do indeed have a voice!

Unfortunately, commercial-in-confidence agreements limit the granularity of analysis publishable, and the limitations of space here prohibit further hypothesis of the implications of the roles of the non-human and how these affect the incidence of creativity. This task is left for another occasion. However, through the inclusion of the non-human in a broader society, the current paper suffices to lend new meaning to Csikszentmihalyi's concluding statement: 'In the last analysis, it is the community and not the individual who makes creativity manifest' (333). The author's input to the hazard management effort was part of a long and emergent process involving innumerable creative actants.

Conclusion

Whilst Robinson's evangelism for a creative revolution in education should be respected and applauded, rather than reification of human creative intention and valorisation of the heroic endeavour, a starting point for better education may be to recognise and champion understanding of universal creativity in which individuals, things, society and culture – the whole assemblage – is emergently situated and how such an understanding of creativity may be directed toward sustaining the whole of things as we know them here in our Earth system. Humanity has proven amazingly creative but is in reality no more vibrant than the rest of matter.

Endnotes

[1] Chomsky, N and Foucault, M 1971 *Human nature: Justice vs power*. The citations here are drawn from a transcript: http://www.chomsky.info/debates/1971xxxx.htm (accessed 27 March 2012)

[2] See the free online resource, *Encyclopedia of human computer interaction*, for an extensive bibliography: http://www.interaction-design.org/encyclopedia/ (accessed 6 April 2012)

[3] Following is an outline of the design process:

1. Take in brief (requirements)
2. Field reconnaissance, interviews and discussions with stakeholders
    a. Focus on CRO users
        i. Describe personas based on real persons
        ii. Construct user scenarios
        iii. Describe use case abstracts
3. Hierarchical Task analysis
    a. Task Breakdown
        i. Flow chart (with reference to specific plans & procedures)
        ii. Map real dependencies
        iii. Query any logical inconsistencies
4. Review requirements
5. Present concept sketch interpreting the brief (Figure 3)
6. Feedback from stakeholders
    a. Project manager
    b. CRO users
    c. Mine safety management
    d. Nexsys™, developers and rules engine consultants
    e. Mine IT systems management
7. Develop concept
8. Deliver comprehensive visuals and graphical components for developers

[4] The full citation is to De Landa, 1997 *A Thousand Years of Nonlinear History,* Zone Books: 47.

[5] A 'Latour Litany' is a term coined by Ian Bogost to describe the lists of things unrelated by conventional logic that (after Latour) writers accounting for ANT and other flat ontologies use to illustrate assemblages of 'actants'. In his blog, Bogost has made available a link to a "Latour Litanizer" script that compiles lists of things from Wikipedia's application programming interface http://www.bogost.com/blog/latour_litanizer.shtml (accessed 6 April 2012)

[6] For ease of comparison, Csikszentmihalyi's original diagram (1999, 315) is reproduced here:

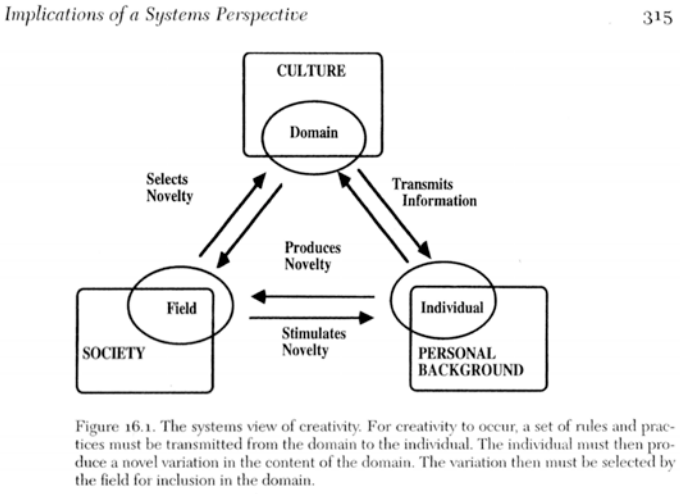

Figure 16.1. The systems view of creativity. For creativity to occur, a set of rules and practices must be transmitted from the domain to the individual. The individual must then produce a novel variation in the content of the domain. The variation then must be selected by the field for inclusion in the domain.

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