Phase change in engineering knowledge production - from an academic to an entrepreneurial context.

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Abstract: *This study uses the characterization of contrasting modes of knowledge production to follow the engineering design and research activity of a group of engineers who migrated from an academic environment to a successful startup firm. Semi-structured interviews were used to construct a narrative approach characterizing their activities in the two settings. We relate their practice to Mode 1 and Mode 2 knowledge production phases and note the importance of a phase change in the transition between the two modes.*

Introduction

Engineering design often tends to be addressed in engineering schools from a positivist perspective. This approach, allied to a clear dominance of academic values oriented to the explanation of scientific facts, arguably produces professionals best prepared for the classic industrial age when processes were more stable and durable than they are today or will be tomorrow. With globalization and the development of new communication technologies the production of knowledge has naturally moved from a linear, explanations-oriented model to one which revolves around networked innovation in a solutions-oriented world and in general we can say that the practice of engineering design in industry and academia have been getting closer. The publication of The New Production of Knowledge (Gibbons et al, 1994) led to considerable attention being focussed on two distinct models of knowledge production, identified by these authors as Mode 1 (associated with a traditional academic discipline-based approach) and the more recently-emerged Mode 2 (a context-driven and problem-focussed process more common in the entrepreneurial sphere). The differences between these two approaches as recently characterized by Figueiredo and da Cunha (2006) are summarized as follows:

	Mode 1	Mode 2
Context	academic, scientific	economic and social applications
Innovation	linear	problems are set and solved in the context of application
Community	disciplinary, homogeneous teams, university based	transdisciplinary; networked; heterogeneous actors
Orientation	explanation, incremental	solution focussed
Method	repeatability is important	repeatability not vital (there may be secrecy/copyright issues)
Quality assurance	peer-review is central	context dependent: may involve peer-review; customer satisfaction
Definition of success	scientific excellence	efficiency; satisfy multiple stakeholders: commercial success

TABLE 1 parameters associated with Gibbons' Modes 1 and 2 of knowledge production

It is generally accepted that engineering design is at the heart of engineering education and is what distinguishes it from other scientific areas within higher education. However, although the practice of engineering design in academia and industry have tended to converge towards a Mode 2 approach, as yet there is relatively little evidence that this has been accompanied by corresponding developments in the engineering education. Jorgensen (2008) argues that educational reforms have tended to focus on the development of Mode 1 model leading to a “crisis in engineering design” with “new professional groups taking over the core and more radical design tasks in companies” and he claims that “this change seems to reduce the classical engineering design departments to focus on incremental innovations and maintaining the existing products and production lines.” He suggests there is a need for a re-thinking as to the “missing elements in engineering teaching” so as to prepare future professionals to face the challenges arising from contemporary technological innovation.

This study considers the work of a group of Portuguese engineering researchers over a 15 year period using the Mode 1 and Mode 2 characterizations and looks for appropriate lessons which can be applied to engineering education to better prepare future professionals. The group in question was part of a successful university research department at the New University of Lisbon throughout the 90’s in the field of environmental engineering and IT. Their Environmental Systems Analysis Group (GASA) was known for its pioneering work in a field that has since become dominated by Google Maps. In 2000, frustrated by the limitations encountered within the academic system, they effectively set aside the projects they had been working on and dedicated themselves to an entrepreneurial start-up. Their YDreams Company has since come to enjoy considerable international success in the interactive space and ubiquitous computing sectors (http://www.ydreams.com/).

Research questions

1. How useful are the Mode 1 and 2 models in characterising the perceptions of the actors in the GASA-Ydreams narrative of this case-study?
2. What implications for engineering education are suggested?

Methodology

The narrative approach has been gaining recognition as a research method and process (Czarniawska, 2004, Pinnegar and Daynes, 2006) while Steve Denning’s recent work also champions narrative as a tool for organizational change (Denning, 2007) . It appears appropriate in this case.

Separate interviews were carried out with two senior members of the group involved in both phases: António Câmara, CEO of YDreams and former head of the GASA group and Edmundo Nobre, YDreams administrator (CFO) and co-founder. The interviewees were previously sent a brief summary of the intended case-study, which included Table 1, and invited to relate their experiences in individual interviews.

Methodology in Practice: Phase 1 - GASA

Context

academic, scientific	*economic and social applications*

António Câmara (AC): Well, we were engineers but we were doing work that was engineering/science where we were essentially emulating the approach of the physical sciences, and not really engineering as such.

(Edmundo Nobre) EN: Environmental engineers have always had a wide-ranging approach by the nature of their very general training.

AC: University groups tend to follow the logic of academia and academic publication and we had a lot of people working on theories of interaction in a way largely oriented to emulating the sciences rather than developing products. We were creating new worlds but following an existing academic model.

Innovation

linear	*problems are set and solved in the context of application*

AC: For example, Conservation International, which has Harrison Ford as its vice-chair, was looking for a visualization system to represent the impact of forest fires on Amazonia and resulting climate change. We submitted a proposal based on our visualization models whereas MIT Media Lab presented a demonstration created by the people who had done the special effects for the film Titanic. The difference being that they already had an operational prototype, a finished product, while we had only a complex model. So, obviously, Conservation International chose them and this episode really got us thinking, made me alter my own perspective quite radically and made me realize that however good our work was technically, we were never going to get very far in today's world using an academic approach.

So while our thinking was "ride the wave", Media Lab was aiming to "put man on the moon" and in the university context it was extremely difficult to create any kind of multidisciplinary laboratory like they had, almost impossible in fact, because there were all kinds of barriers stemming from the fact that we worked within academic disciplines. So, when we worked in the Environment Department we were expected to be dedicating ourselves to working on the environment, even if we were able to come up with something useful for automobiles ....

Community

disciplinary, homogeneous teams	*transdisciplinary; networked; heterogeneous actors*

AC: It was basically research work and recognition came from other researchers. In other words, our community was that of investigators the world over within our area.

EN: We were always in contact with the best work going on internationally and made a point of encouraging our graduates to go to work at the top research centers. They in turn often stayed on and tended to cite our work which gave us more visibility.

AC: Then at a certain stage we came up against other communities, ones like MIT, not the traditional scientific community, who were leaders in the field and this was something of a shock for us.

Orientation

explanation, incremental	*solution focussed*

AC: At GASA it was basically the kind of scholarly approach to which the majority of university courses here aspire; which means that they were very much built around knowledge, scientific knowledge, stabilized knowledge.

EN: We had the first virtual reality lab in Portugal, created for Expo 98 in Lisbon, complete with a set of instruments that were groundbreaking in world terms at that time in the area of over land navigation. We were the first country to have this infrastructure set up but it dwindled out, because policy-wise its value wasn't recognized. It was an over-ambitious project, probably ahead of its time, and like so many other breakthroughs within universities because there isn't an entrepreneurial or commercial perspective then things get bogged down and bit by bit come to a halt.

Method

repeatability is important	*repeatability not vital*

EN: Our objective at that time was to produce papers whereas we came to see that at other centres like MIT the object was more to produce enterprises and so they had an applied research approach and received a lot of financial support from industry.

Now MIT had funding to buy super-computers whereas we here could only invest in people, people who were capable of developing powerful algorithms which allowed us to overcome our less advanced hardware and what we achieved was certainly on a par with the best we saw at international level.

Quality assurance

peer-review is central	*context dependent: may involve peer-review; customer satisfaction*

AC: We were, of course, very aware of ISI indexing (…) and getting our work accepted for major conferences which are extremely competitive, with an acceptance rate of around 3%.

Definition of success

scientific excellence	*efficiency; satisfy multiple stakeholder;, commercial success*

AC: What we basically wanted was to achieve worldwide recognition within the academic milieu through papers, articles and later books.

Metholology in practice: Phase 2 – Ydreams

Context

academic, scientific	economic and social applications

AC: I realized that to be competitive with the top laboratories in our field we would need to have professional level management, accounts, public relations … in short to have an enterprise-like structure.

EN: We had come to the conclusion that if we couldn't do what we aimed to do within the academic system then we would have to do it on the outside; so basically we went ahead and set up the company.

EN: When we first set up YDreams, the wide-ranging background of our team stood us in good stead. Now this transdisciplinary approach has paid off and in fact we have people who originally trained as environmental engineers holding down key positions in accounts, programming and project management.

Whereas in our GASA days we used to play around with ideas and ask "OK, how could we get this on the market?" now it was more in a case of "OK, how can what we do that will be important for the market?"

Innovation

linear	problems are set and solved in the context of application

EN: We have our R&D section, YLabs, which has a variety of functions and these include:

- assisting in developing the technological infrastructure for the company itself
- short-term research focused mainly on product development for our clients
- long-term research which is looking to identify future paradigm shifts so that we can be right there when things are happening. In this respect, I would give the example of our work on interactive spaces which up to now has been entirely in the digital domain but as this sector has become successively more the province of large international competitors, we have to be agile and so we have been working on the application of recent innovations in materials sciences and bubble-jet technology to apply our knowhow to the development of novel interactive spaces in the physical domain.

Community

disciplinary, homogeneous teams	transdisciplinary; networked; heterogeneous actors

AC: Now I would say that our community is completely different: we do what we do so as to satisfy two groups of people: our clients and our investors.

Orientation

explanation, incremental	solution focussed

EN: We set out to adapt our practice from the GASA days to create a structure which was much more dedicated to industry, with a strong focus on applied research, one which would in turn be supported by industry. Our focus was to be on the real world products rather than on publications. We aim to be a cutting edge company.

Method

repeatability is important	repeatability not vital

AC: Now it really feels like we are doing engineering design and that we have left the world of classic research. One consequence of this is that now when we produce something new our first priority is to take out a patent and if we have time afterwards we may write it up in a paper. So this changes the dissemination process quite radically.

In the company we have continued to carry out research, the difference being that now we are very much more in the Man on the Moon mould. Now we really want to create products and the objective of all our research, pure or applied, is precisely product-focused. We are not at all interested in repeatability – we want to be unique, that's what it's all about!

Quality assurance

peer-review is central	context dependent: may involve peer-review; customer satisfaction

AC: So we are creating intellectual property, very important to appeal to clients and this has been fundamental in attracting investors in the various phases the company has gone through. To be competitive we have to bring value to the market.

Definition of success

scientific excellence	efficiency; satisfy multiple stakeholders; commercial success

EN: We originally wanted to leave academia and conquer the world! Success for us has two dimensions: obviously we want to become millionaires (laughs) but on the other hand we would like to be a company which helps give Portugal a strong international technological presence on a par with, say, what Nokia has in Finland. That is a company which altered their national panorama and we would like to think we could one day make a similar claim, that is to really make the difference between what Portugal is today and what it could achieve tomorrow – help to create a technology driven nation.

Discussion

The data presented show that although there was a predominance of Mode 1 characteristics in the GASA phase, there were already some signs of a Mode 2 in that there was a degree of transdisciplinarity in the research team and a concern with providing solutions to clients (creating virtual instruments for Expo 98, competing with MIT for projects). Equally, in the current entrepreneurial context, although the interviews would indicate a strongly Mode 2 perspective overall, it is worth mentioning that the YDreams headquarters adjoins the university campus where GASA used to operate, the CEO continues to lecture there and there appears to be a certain degree of synergy between the two so it is probably true to say there hasn't been a complete abandonment of the Mode 1 ethos. So although the Mode 1 and 2 characterizations are seen to be useful as a way of characterizing in a broad sense the knowledge production activity of the group of engineers in question and they help us accompany what seems to have been a significant phase change in the work of the group, it should not be seen as an either/or way of describing the real-world activity involved.

The interviews show a growing awareness of the constraints of the Mode 1 context the group operated in during the 90's ("things got bogged down"; frustration with "ride the wave" thinking) which reached a critical point in the year 2000 when they decided to set up YDreams. This point can be considered a phase change in the sense that the term is employed in systems and complexity theory to refer to a system in a given state which undergoes progressive disruption and achieves equilibrium by transition to a new state (Baufu, 2008). Future research is expected to include a deepening the analysis of the GASA and YDreams contexts described here by enriching the interview data presented with additional data about this case such as documentary records from the contexts under study. At the same time we are looking towards acquiring similar data from other groups who have gone through a similar phase change process.

Finally, although the sample in this study is small, we believe that it has potential for organizational learning in a context where "history is not generous with experience" (March et al, 1991) and within our national context it could be the kind of historical event which can contribute to organizational change within engineering education institutions through its authenticity and metaphorical power.

The findings would appear to reinforce calls for a Mode 2 approach to engineering design in syllabuses, perhaps adopting approaches similar to those described in the US (Dim et al 2005; Atman et al 2007) or South Africa (Winberg, 2006). Initiatives like the Purdue University EPICS program (Oakes et al, 2000) or Georgia Tech's Learning by Design (Kolodner et al, 2003) would seem appropriate approaches to develop transdisciplinary competences at undergraduate level.

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