Engineers and their practice: a case study.

Bill Williams
CEG-IST, Lisbon and ESTBarreiro,
Setubal Politechnic Institute,
Barreiro, Portugal
bill.williams@estbarreiro.ips.pt

José Figueiredo
CEG-IST and IST, UTL,
Lisbon, Portugal
jdf@ist.utl.pt

***Abstract*— There has been a growing awareness of the need for models of engineering practice in recent years and the publication of The New Production of Knowledge [1] by Gibbons led to considerable attention being focused on two distinct modes of knowledge production: Mode 1 associated with a traditional academic discipline-based approach and the more recently-emerged Mode 2, a problem-focused process more common in the entrepreneurial sphere.**

The case-study reported here originally set out to use Gibbons' models to characterize the work of a group of Portuguese engineering researchers over a 15-year period. The study employs a qualitative methodology and narrative approach to characterize practice within this group of engineers so as to look for appropriate lessons that can be applied to engineering education to better prepare future professionals.

Analysis of the information gathered during the study has caused us to question our original model of engineering practice and leads us to the conclusion that the Unifying Model recently proposed by Trevelyan [2] could represent a better fit to characterize the activities of this group and would suggest a need to gather empirical data on engineering practice.

Keywords*: *Model, engineering practice, knowledge production, case study

I. Introduction

Engineering design often tends to be addressed in engineering schools from a post-positivist perspective. This approach 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 by Gibbons et al in 1994 [1] led to considerable attention being focused 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-focused process more common in the entrepreneurial sphere). The differences between these two approaches as recently characterized by Figueiredo and Cunha [3] are summarized as follows:

TABLE I. PARAMETERS ASSOCIATED WITH GIBBONS' MODES 1 AND 2 OF KNOWLEDGE PRODUCTION

	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

It is often assumed in the literature that engineering design is at the heart of engineering education and is what distinguishes it from other scientific areas within higher education [2]. 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 [4] 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. To better understand the practice of today's engineers and its implications for education it was decided to focus initially on one national company.

In 2009 the US-based consultancy firm, Strategos, polled 186 CEOs and senior figures in leading Portuguese companies to gather data on which international and national firms they considered to be the most innovative [5]. The national company with the highest vote was YDreams, a recent startup which was created in 2000 when a group of engineers from a successful university research department at a Lisbon university felt the need to move from a university to an entrepreneurial context. YDreams has since had considerable national and international success in the areas of interactive spaces.

The authors decided to begin a pilot-study of the YDreams team to trace their historical development and see what lessons could usefully be drawn for engineering education by studying the knowledge production and practice of such an innovative organization. The key engineers in this startup were originally 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/).

A. Research questions

Is the Gibbons Mode 1, Mode 2 model appropriate to characterise the engineering practice of this group of engineers?

What can we learn about engineering practice in an innovative startup company by interviewing key players in its history?

II. Methodology

The initial methodology chosen employed what Cresswell refers to as an exploratory qualitative design [6]. This methodological approach has been used successfully in social science research for some years and has more recently also come to be adopted in engineering education research, usually as a prelude to quantitative methods within a mixed-methods methodology [7].

Accordingly, Gibbon's Mode 1 and 2 Model of knowledge production (and engineering design) were used as a basis for interviews with two of the founders of the firm and the narrative data obtained was analysed qualitatively, guided by the work of Czarniawska on narrative research methods [8].

Separate lightly-structured 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; they were not given specific questions to answer but rather encouraged to relate their practice in the context of the GASA research group and contrast this with their current activity in the entrepreneurial context of YDreams.

The interview transcripts were then analysed for material relevant to the Mode 1 and 2 parameters and organised under the relevant headings set out below. Subsequently a bracketing process [6] was applied to these first extracts and the transcripts were scanned for additional references to engineering practice. This produced two further observations and these are included in the Discussion section.

All extracts quoted in the paper were translated from the original Portuguese transcripts and subsequently checked for accuracy with the interviewees.

III. Results

The interview data has been structured here using the Mode 1 and 2 parameters. The corresponding characterisations are summarised in the boxes at the beginning of each section with Mode 1 on the left in each case.

The narrative information relating to the university context is set out first and after that the same organizational structure is employed for the extracts describing the entrepreneurial context.

A. University Context: GASA

1) 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.

2) 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 ....

3) 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.

4) 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.

5) 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.

6) 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%.

7) 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.

B. Entrepreneurial Context: Ydreams

1) 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?"

2) 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.

3) 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.

4) 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.

5) 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!

6) 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.

7) 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.

IV. Discussion

The data presented suggest that, although the Mode 1 and 2 characterizations can be seen as useful here to characterize in a broad sense the knowledge production activity of the group of engineers in question and to help us accompany what seems to have been a significant phase change in the work of the group, they should not be seen as an either/or way of describing the real-world activity involved.

In addition, having bracketed the previous extracts, a rereading of the interview transcripts threw up some additional comments, which led us to rethink our original model of engineering practice and reexamine our concept of what engineers actually do:

EN: Right now, I recall off the top of my head that our head of Quality, head of Research, head of Software, our top programmer and the account managers of our best accounts all come from an environmental engineering background and this pluridisciplinarity, the capacity to handle a broad sweep of areas is very valuable in a company like ours. These roles involve heading up teams where skills of dealing with both a range of multidisciplinary projects and with their commercial aspects are vital. Obviously when we get to the execution, programming, design and so on then we will call upon our specialized people for these very specific functions.

AC: What worries me is that engineering courses in our national universities don't have a tacit curriculum like you can find at top international institutions: our graduates have the technical skill; they can solve problems but are not good at explaining them. One feels they were well trained in problem-solving but at the expense of important skills like analyzing, communicating and debating which contribute to the kind of structured thinking we need.

Noting that a significant number of engineers in the company were in posts of responsibility outside conventional engineering domains and that the CEO identifies communication skills as a priority for success, has lead us to see limitations in our original model of engineering practice which was based around engineering design and knowledge production and encouraged us to look for alternatives, particularly for models based on an empirical approach. Although the vast majority of literature on engineering practice tends to view it in terms of design or technical problem-solving [9, 10, 11, 12, 13] such models are rarely based on empirical studies analyzing what engineers do.

A model proposed by James Trevelyan of the University of Western Australia in 2009 does however address these issues [3]. The Unifying Model of Engineering Practice sees engineering as social system involving a sequence of steps common to most engineering activities and which are enclosed within a scaffold that continually guides the implementation steps towards the intended objectives. The scaffold in turn involves continual interaction between all the participants, including the client, financiers, engineers, contractors, suppliers, production and service delivery workers, technicians, regulators, government agencies, local community and special interest groups. This model grew from a longitudinal study of engineering graduates in Australia [14, 15] which showed that the majority spent less than 30% of their working time on specialized problem-solving and technical coordination emerged as the most frequently mentioned activity. The study found that graduates asked to estimate time spent on different aspects of their work estimated that nearly 60% of their time is spent interacting with other people, including working face to face, meetings, correspondence, reports and working with human-readable data in information systems and this finding would tend to give weight to Antonio Câmara's comment on the importance of communication skills.

V. Conclusion

To quote Trevelyan: "Engineering works. It could work better, however, with improvements in education and an identity in which the social and technical embrace each other with equal prominence." [3] Accordingly it is important to have empirical data on the activity of engineers in successful companies so as to achieve a good alignment between engineering education and the needs of future engineers and their employers.

Our current research, carried out in collaboration with the University of Western Australia, involves empirical data collection from engineers in YDreams and other firms considered innovative in the Portuguese context to see to what extent the Australian data and the Unifying Model are relevant to the southern European context and how this model can help adapt engineering education to the needs of tomorrow.

References

[1] Gibbons, M. et al, The new production of knowledge: The Dynamics of Science and Research in Contemporary Societies, Sage Publications, London, 1994.

[2] Trevelyan, J. P., "Steps Toward a Better Model of Engineering Practice," presented at the Research in Engineering Education Symposium, Cairns, Queensland, Australia, 2009.

[3] Figueiredo, A. D. & Cunha P. R., "Action Research and Design in Information Systems, Two faces of a single coin," Chapter 5, Information Systems Action Research: Bridging the Industry-University Technology Gap, Ned Kock (Editor), Springer /Kluwer, 2006.

[4] Jorgensen, U, "Engineering Design in Theory, Teaching, and Practice - The Construction of Design Synthesis and Methods and Contemporary Challenges," presented at Global Perspectives on Engineering, International Network for Engineering Studies Workshop, Lisbon, 2008, available at http://www.inesweb.org/node/202 on 30 March 2009.

[5] Strategos, "Business Innovation Survey Report (2009), Portugal," (in Portuguese) available at http://www.strategos.com/articles/Strategos_BIS2009_Report.pdf on 30 October 2009.

[6] Creswell, J.W. 2007. Qualitative inquiry and research design:Choosing among five approaches, 2nd edition. Thousand Oaks, CA:Sage Publications, pp 52, 361.

[7] Borrego, M., Douglas, E. P., & Amelink, C. T., "Quantitative, Qualitative, and Mixed Research Methods in Engineering Education," Journal of Engineering Education, 98(1), 53-66, 2009. available at http://media.web.britannica.com/ebsco/pdf/36/36587532.pdf, 30 October 2009.

[8] Czarniawska, B. Narratives in social science research, Thousand Oaks: Sage, 2004.

[9] Atman C. et al, "Engineering Design Processes: A Comparison of Students and Expert Practitioners," Journal of Engineering Education, 96(4), 359 -379, 2007.

[10] Jonassen, D., Strobel, J., & Lee, C. B. "Everyday Problem Solving in Engineering: Lessons for Engineering Educators," Journal of Engineering Education, 95(2), 139-151, 2006.

[11] S. Sheppard, et al, "What is Engineering Practice?" International Journal of Engineering Education,. Vol. 22, No. 3, pp. 429-438, 2006.

[12] Vincenti, W. G. What Engineers Know and How They Know It: Analytical Studies from Aeronautical History. Baltimore: The Johns Hopkins University Press, 1990.

[13] Vinck, D. (Ed.), Everyday Engineering: An Ethnography of Design and Innovation. Boston, 2003.

[14] Trevelyan, J. P. "Technical Coordination in Engineering Practice," Journal of Engineering Education, Vol. 96, No. 3, pp. 191-204, 2007.

[15] Trevelyan, J. P. (2009). "Engineering Education Requires a Better Model of Engineering Practice," presented at the Research in Engineering Education Symposium, Cairns, Queensland, Australia, 2009 .