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UK DESIGN RESEARCH AND ITS IMPACT ON INDUSTRIAL PRACTICE FOR PRODUCT DEVELOPMENT

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Abstract

Over the last 12 years Engineering Design has attracted significant research funding from EPSRC and indirect support from the Teaching Company Schemes in the UK. The question now being asked is what has been the impact on Industry and Academia in terms of the deliverables from this research? Has it affected the research rating of the University and / or has it produced major gains for Industrial competitiveness, innovation and productivity?

A Royal Academy of Engineering study was commissioned to look comprehensively at some 9 UK Universities with a good track record in design and design research. In particular, following visits to the Universities, key issues and underlying practices were identified in terms of industrial exploitation from the design research, the extent of the academic-industrial collaboration and the benefits to academia.

This paper identifies the critical success factors and the generic strategic actions by academics and industrialists that have helped establish real products and design process successes for industry, whilst improving the research rating of the academic department.

This paper gives an insight into how design research is progressing in the UK and the benefits realised by industry.

Keywords Industry, Collaboration, Benefits, Academia

1.0 Introduction

The Royal Academy of Engineering has for the last 15 years been instrumental in activating good practice in Engineering Design teaching throughout almost 50 Universities in the UK. The Academy's scheme for the Visiting Professors in Principles of Engineering Design has been a major success story in this respect.

More recently, with the support of the DTI, the Academy was instrumental in supporting UK SME's through the P^3I (Partnership for Profitable Product Improvement) scheme. Some 450 manufacturing companies were visited by special design advisers to help them to improve their performance in developing products by adopting a unique methodology. This unique self-help methodology continues to be adopted by SME's in their efforts to improve their competitiveness and productivity.

Over the last 12 years, Engineering Design research in UK Universities and Colleges has attracted significant funding. The Engineering and Physical Sciences Research Council (EPSRC) initially funded the creation of 10 Engineering Design Centres and has made numerous individual research grants throughout the UK Universities. Similarly, there is clear evidence that the DTI/EPSRC Teaching Company Scheme (TCS) has provided an excellent mechanism for joint industry/academic research and development on Engineering Design issues within UK manufacturing companies.

In recent times the Royal Academy of Engineering formed a focus group to investigate issues connected with the UK industrial exploitation of engineering design research. Following wide scale consultations with industry, academia and the above Academy Visiting Professors, a paper was presented to ICED 2001 entitled "Putting Design Research to Work", by Dr Nigel Upton & Professor Ivan Yates, detailing the conclusions from all three above parties (Ref.1).

This study looked at the take up and awareness of engineering design research outputs amongst a group of SMEs who were known to be active product developers (either as Millennium Product winners, or as participants in The Academy's P^3I project). The conclusions of this study showed a very low take up, and even low awareness, of engineering design research undertaken by UK universities. The consensus of both the companies and most of the academics was that there were few mechanisms, or even incentives, for UK academics to see the results of their research exploited by UK companies.

Given the facts of this wide ranging paper, it was considered essential and timely that a more focused study be carried out where known good design research would appear to exist. Whilst not an exhaustive list, some 9 UK Universities were selected where it was considered that they had achieved a truly strong relationship with industry and engineering design research was perceived to have impacted and translated into significantly improved design practice.

Over the period January – March 2002, Professor Sheldon was commissioned to visit the Universities of Bath, Cambridge, Coventry, Hull, Imperial College (IC), Liverpool, Newcastle, Strathclyde and the University of Wales Institute, Cardiff (UWIC). Mr. David Foxley (Manager – Engineering Design Education) of The Academy was also involved on many of the visits. We considered that it was important a spread of disciplines and research groupings were investigated across the visits and discussions.

Detailed discussions were held with many of the key design research staff at each of the Universities, using a basic listing of “starter” questions (see Table 1) that would draw out: the scale of industrially relevant research, the critical success factors leading to excellent academic/industrial collaboration, the challenges addressed and overcome, achieving academic and industry objectives concurrently and the nature of the industrially relevant research outcomes.

Table 2 provides some important details on the scale of the design research and the degree of academic/industry collaboration during 2001. It should be noted that on the grounds of confidentiality, some Universities provided only limited information against the criteria requested and hence the tables are not wholly comprehensive.

Following the visits to academia, detailed conversations were held with 2 or 3 of the collaborating companies associated with each University on engineering design research. In particular, it was essential that deliverables to industry were quantified and qualified, whenever possible, in order to measure the scale of industrial exploitation of the engineering design research.

This paper looks to identify appropriate practices of successful engineering design research in academia, clarify the real benefits to industry, establish the underlying practices that achieve success, together with the key overall factors that have contributed to successful outcomes.

2.0 The Real Benefits to Industry

“*To maintain prosperity through all sectors of the UK, be they private or government, a strong product development performance by the manufacturing sector is necessary. New products generate new sales; they lead to new manufacturing investments, plus new jobs in the manufacturing and service sectors. In turn, this increases gross domestic product and thereby government revenues to fund infrastructure and services. It is a virtuous circle, but in the UK it is in danger of becoming a vicious circle*” (Ref 2).

Within this real context, the study has identified encouraging signs where academic/industry collaborative design/product development research activities are bringing real deliverables to the manufacturing sector.

Following the visits to the 9 Universities, it was agreed that 2 or 3 recommended industrial contacts would be followed up to establish the real deliverables that had emanated from collaborative engineering design research with their respective universities. Whilst space does not allow all the specific comments to be detailed, a number have been highlighted as examples of the general picture that emerged.

It could be argued that each of the industrialists was hand picked by each University. However, it is important to note that real positive deliverables were achieved in all cases. Without exception, all the industrialists considered the collaboration with academia to be of real benefit. As an overall impression, the industrialists believed significant improvements in their competitiveness and productivity were gained.

However, in a number of cases this was much easier for the industrialists to qualify than quantify.

The form of deliverables varied from company to company. However, they break out naturally into 2 broad groupings of a) product design developments (including tools and techniques) and b) design process and systems improvements.

2.1 Product Design Developments

There has been a fairly widespread set of deliverables across 7 of the academic/industry collaborations at Bath, UWIC, Liverpool, Coventry, Newcastle, Strathclyde and Hull. The scale of these product developments has been immense, intellectually challenging and significant in terms of risk to both parties.

They have resulted in new software packages related to vehicle interior designs, pedestrian/car impact modelling, engine in-cylinder modelling, continuously variable transmission modelling, tolerance capability, design for assembly (DFA), stress concentration analysis, design for safety, hydraulic/control circuitry, etc.

In addition, through such collaboration, a rich array of new hardware ideas/concepts have been taken through to production under strict time, quality and cost constraints. Such products were much more than "solving a problem" and were based, undoubtedly, on sound research principles as they included:-

- considerable knowledge and market research
- original design ideas and innovative thinking
- the spectrum from industrial to engineering design, new materials and advanced manufacture methods
- the integration of and implementation of design tools (DFA, DFM, FMEA), analytical design tools (FEM), 3D CAD/CAM solid modelling, visual and rapid prototyping on a lean product development programme.

Whilst there was a considerable amount of confidentiality entailed, it was possible to elicit that such products included underwater medical life support systems, materials selector, electronic publishing, design workbooks, next generation payphones, environmental testing smart tags, Expo 2000 Japanese pavilion design, the Guthrie pavilion design, lift control system, steering wheel driving aid, electronic equipment, consumer products, automotive, medical, aerospace, defence equipment, etc. Many more were discussed, but due to their commercially sensitive nature, cannot be disclosed.

Typical quotes from industrialists proved to be constructive and took the following forms:

- *"The software was robust, trustworthy and delivered on time."*

- *"The design software has been introduced globally across the company."*
- *"Fresh ideas were brought in that jointly produced good concepts and a workable production system."*
- *"We use the university for new product development as we can't get good design graduates ourselves."*
- *"They changed the methodology of many years standing on the optimization of steam turbine designs."*
- *"The software achieved integration across all design packages."*
- *"Achieved an overall product cost reduction of 68% and an assembly time reduction of 25%."*
- *"A right first time solution with reduced financial and technical risk was achieved with no significant increase in cost."*
- *"The assembly part count on the product was reduced from 55 to 20 and assembly time from 35 minutes to 70 seconds."*
- *"It is believed that the availability of the design tool will drive forward demand for legislation and codes of practice."*
- *"The involvement of the university resulted in a superior product as well as significant cost savings for the company*."

Many of the comments were made repeatedly by the various company representatives.

2.2 Design Process and System Improvements

These were delivered to the collaborating industries, primarily by Cambridge, Strathclyde, Coventry, Liverpool, Imperial College, UWIC and Newcastle University. The challenges achieved were concerned with university staff working closely within the environment of the companies and far less at the University.

The research was concerned with critical issues to a company, yet for the most part, the deliverables proved much more difficult to quantify by the industrialists questioned.

The design research across the spectrum was clearly related to understanding and improving:-

- The design related business processes.
- Communications between product development staff and teams.
- Motivation, formation and management of virtual design teams
- Communications between virtual design teams (processes/systems and tools).

By the nature of the above research areas, the skills of the University staff took on a different form because of having to work closely within the company environment and understanding the current design/product development practices and organization (structures and politics).

It is clear from the industrial responses, that the successful research activity required a special set of people skills from the academics. They included staying power, continuity, exacting regular progress meetings, political skills, compatibility not arrogance, listening and seeing, plus keeping it simple.

Typical quotes from the industrialists were constructive and took the following forms:-

- *"They improved the design process to achieve faster, better, cheaper products."*
- *"Influenced the design knowledge search and re-use process considerably."*
- *"Codified the design process and reduced quotation costs by 20% in the estimating process."*
- *"We gained the benefits of known best design practice."*
- *"The research encouraged the company to improve its business processes and use cross functional teams to better advantage."*
- *"The work helped to produce generic knowledge of the ways in which the process behaved to facilitate the design of product specific processes."*
- *"We recognized that the university design staff could deliver the goods."*
- *"The research reduced considerably the cost of generating new designs."*
- *"Recognised a world class team of forward thinking design staff."*
- *"The research helped us to have joined up thinking and product development plans."*
- *"Given the design research output, senior technical staff are now free to take on a more strategic role."*
- *"Industry likes a relationship with academia in order to keep up with the state of the art, as well as to benchmark with competitors."*

It must be restated that the industrialists, without exception, rated highly the research activities on design process/system improvements, brought about within their companies.

3.0 Underlying Practices that Achieved Success

- Of the 9 Universities visited, many have succeeded because of the charismatic pioneering approach by one or two senior academic staff towards engineering design research.
- A supportive Vice Chancellor/Principal who understood the need for the collaboration with industry to be broad based, embracing the spectrum of near market to long term research in engineering design.
- Academics who have the ability to work within industry, build up mutual trust and confidence and assist in identifying their design research needs.
- A clear strategy to build multi-disciplinary design research teams that work closely with key individuals in particular industries.
- Playing to the strengths of key design research staff with an applied approach and good industrial experience, when matching with industry. Not "being all things to all people".

- A well-chosen industrial advisory board, steering committee or industrialists' club that supports, understands and implements (where appropriate) the design research activities.
- Ensuring any initial collaboration with an industry meets their time, cost and quality requirements.
- Coming to a common early up-front understanding on deliverables, regular honest communications, plus measuring the risk as the potential project is initially discussed.
- Well equipped design facilities, CAD/CAM, CAE and Rapid Prototyping facilities for industrial use, have been a major factor in achieving substantial industrial collaboration in 4 universities.
- Teaching Company Schemes, final year projects from industry, bespoke short courses and undergraduate placements have been effective vehicles on which research has been built.
- Adopting European Regional Development Funding (ERDF), TCS, Industry and Regional Development Agency (RDA) resources, as alternatives to EPSRC, for priming design research and supporting activities.
- Royal Academy of Engineering Visiting Professors in Principles of Engineering Design were seen to have played a major role in building sound collaborative links with industry.
- Critical factors for the academics, leading to good collaboration, included staying power, continuity, keeping it simple, taking the trouble to be compatible, listening and seeing and good political skills.

4.0 Conclusions

4.1 From this focused detailed study of UK Universities where engineering design research is a major discrete activity, it has been established that both vigorous and exciting industry/academic collaboration exists with SME's and large manufacturing/engineering organisations.

4.2 Without exception, all 9 Universities have established a range of research activities that are providing real value adding deliverables through new products and processes across a wide variety of industry.

4.3 A number of the Universities are collaborating actively on design research with a minimum of 20 different companies at any one time.

4.4 Whilst not without its challenges, there is significant evidence that design research staff are managing to meet the expectations of industry, whilst at the same time achieving excellent ratings between 4 - 5* in the 2001 research assessment exercise.

4.5 In general, the industries have made it clear that the collaboration continues to produce many new research ideas (both product and process), has built up a sound basis of mutual understanding and provided a stable platform for increasing design research activity in the future.

4.6 Up to the present time, at a number of the Universities, the competitiveness and productivity of industry has been enhanced by the collaboration on design research.

4.7 Whilst the position varies somewhat across the Universities visited, a real deliverable to industry has been the number of engineering design research postgraduates, who on completion move into responsible design/product development/business process re-engineering positions in industry or consultancy.

4.8 The successes achieved have been a result of a supportive academic leadership, charismatic pioneering design researchers who relate to industry and a University strategic direction where design research embraces both near market and long term collaborative activities.

4.9 TCS, ERDF, Design Council, RDA and Industry, as additional to or alternate from EPSRC, have been a major influence on the adoption of design research with industry.

4.10 Company spin offs, self-employed businesses, seeded companies, industrial postings (from academia), academic postings (from industry) and industrial clubs have been a success feature at a number of the Universities.

References

(1) N.Upton, "Putting Design Research to Work": 13th International Conference on Engineering Design - ICED 01, Glasgow, August 21-23 2001.

(2) C.B.Mynott, "A Strategic Overview of UK Product Development"Journal of Engineering Design, Vol. 12, No.1, 2001, Publishers Taylor & Francis.

Tables

Table 1-Basic Listing of Starter Questions to Universities

1. Quantify measured deliverables as perceived by 2 or 3 companies (value added to their products/processes/systems).
2. Over the past 5 years-how many companies have established a strong design research link with yourselves.
3. Identify the methods and strategies employed to establish industry links.
4. Quantify the types of industry needs in design research.
5. How do industry needs match your academic objectives
6. Proportionally, what has been the scale of design research compared to other Dept/Faculty engineering research over the past 5 years.

7. If success has been achieved – what metrics have been adopted to measure success
8. What have been the major challenges/problems in collaborative design research with industry – how were they overcome.
9. What have been the 6 critical success factors on design research.
10. How did your dept/faculty organize their staff to bridge the gap and link with industry.
11. What company spin offs occurred as a result of design research.
12. What Club arrangements have been set up with industry on design research.
13. Have any industrial postings occurred into academia on design research.
14. Have any academic postings occurred into industry on design research.

Table 2- 2001 University Statistics

UNIVERSITY	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**
TOTAL £K		1626		300	1413	400	567		
%EPSRC	70	55	40	27	10	0	10	45	0
%TCS	25	0	40	12	0	0	10	21	28
%REG/EU		7	15	4	48	10	7	34	7
%IND	5	38	5	57	42	90	73		65
STAGES i	70		65	60	60				30*
DES. RES. ii	20		30	15	30				30*
iii	10		5	25	10				40*
JRNL.PAPERS	9	15	12	9	82		9	9	
IND. EMPLOY	25	28	9	10	30	3			
<250	5	10		5	6		3		
250-1000	16	10		0	3		2		
>1000	4	8		5	21		7		
RAE RATING	5*	5*	4	4	5*	5*	4	4	4
SPIN OFF CO	0	1	0	0	3	0	0		1
DES. STAFF									
FT ACAD.	10	15	9	4	21	7	5	6	10
FT RA/PDOC.	8	32	3	3	15	0.5	14	6	7
PT RA	1	1	1	3	0	1		0	4

TOTAL £K — Total design research income/year plus Annual % income from EPSRC, DTI/Teaching Company Scheme, Regional/European Union & Industry.

STAGES DES RES - i) Research leading to an enabling tool or technique
ii) Research leading to a methodology to implement above
iii) Implementation in an industry/work environment

JRNL. PAPERS - No of engineering design papers published/year.

IND. EMPLOY - No of Industries employed in collaborative design research with numbers of employees indicated.

RAE RATING -	Research Assessment Exercise Rating (2001) for Design Research Department or the Overall Department.
SPIN OFF CO -	No of spin off companies from design research activity
DES STAFF -	Full time academic (FT ACAD), Full time research assistant/post doctorate (FT RA/PDOC), Part time research assistant (PT RA).

* This data applies to year 2000