Interdisciplinarity: Creativity in collaborative research approaches to enhance knowledge transfer

Janet Coulter

Research Institute for Art and Design (RIAD), University of Ulster, Belfast, UK

Abstract. This paper outlines how collaborative approaches were used to successfully generate research opportunities and enhance knowledge transfer in the development of new products. The researchers were drawn from across four disciplines within the University of Ulster and worked closely with an industrial partner to develop and test new approaches to the design and development of soft body armour. The paper highlights the drivers needed to support interdisciplinary collaboration and examines motivations for co-operation between industry and universities in the transfer, exchange and management of knowledge. A research project, highlighting two case studies demonstrates that design- and science-based partnerships can be successful in creating and transferring new knowledge.

Keywords: Interdisciplinarity, Collaboration, Knowledge Management, Knowledge Exchange, Innovation

1 Introduction

The Company partner cited in this paper is a manufacturer of soft body armour. At the time of the research, the Company was engaged with The University of Ulster in a 27 month Knowledge Transfer Project (KTP) [1] to develop new products for new markets. In developing solutions for the Company, an in-house research and development (R&D) capacity was established. However, the Company had little design experience and some ideas suggested for R&D were outside the scope of the agreed objectives for the KTP. External funding was obtained by the author to research and explore ideas, which could potentially benefit the KTP. These projects were significant as they drew from diverse sources of knowledge. Expertise from fashion and textiles, sports and exercise, health and rehabilitation sciences and engineering all contributed to the research. This unique collaboration yielded interesting results and demonstrated how a cross-disciplinary approach to research can enhance knowledge transfer and contribute to economic growth.

The paper is contextualized with an examination of the reasons why academics choose to engage in collaboration and suggests the characteristics that typical cross-collaborators should possess. It outlines drivers for interdisciplinary alliances and motivations that steer industry to seek partnerships with universities and highlights the challenges that design-led and science-based partnerships need to overcome to reach successful outcomes.

2 Rationale for the Research

Strategic commitment is vital for innovation to be achieved (Rixon, 2003) and the Company was aware that R&D held the key. R&D feeds design with new technologies, materials and processes (Cooper and Press 2009) and provides strategic direction to inform potential research for new products. Cohen and Levinthal (1990) argue that companies with R&D capabilities are better equipped to utilise external information effectively. As the KTP project continued to generate new R&D, the Company realized that external knowledge would be required to research and explore the ideas. In seeking opportunities to create new knowledge without investment in new technology, the key challenges were to determine if: (i) existing technology within the University could be applied to the new design processes to provide novel solutions that could enhance competitive advantage and (ii) to establish how any perceived competitive advantage could be measured. The two case studies described in this paper demonstrate how, if a diverse knowledge skill set can be harnessed effectively, an open-innovation approach can produce successful results.

3 Case Studies

3.1 Case Study 1: 'SweatSmart'

New knowledge of technical textiles had been embedded in the Company as part of the KTP and the Company now sought to exploit this with the intention of creating a USP for its new product range. One issue deemed essential to explore was moisture management. Armour solutions have up to fifteen layers of Kevlar, plus laminates sealed inside a polyurethane cover, creating a thickness of approximately 25mm. These are then inserted into the back and front of a carrier vest, causing poor wicking properties. This combined with high external temperatures that military personnel may be subjected to, or stressful situations such as riot control, cause the wearer to perspire heavily. This can potentially lead to dehydration and disorientation, resulting in the wearer having reduced judgment and cognitive performance abilities. A study on dehydration in soldiers from tropical regions of India concluded that significant decrease in mental performance occurs at dehydration levels of 2% (Gopinathan, 1988). Lieberman (2007) provides a comprehensive review of the study and Cian et al (2000) cite increased fatigue and reaction time to decision-making and decreased short-term memory resulting from dehydration.

The investigative research, dubbed *'SweatSmart'* was initiated to determine whether innovative design, combined with performance fabrics could be engineered to improve moisture management and potentially reduce the associated physiological effects. An experiment was devised (Coulter et al, 2009) and implemented in a controlled environment in the University of Ulster, using an acclimatisation chamber at the Sport & Exercise Sciences Research Institute (SESRI). Researchers at SESRI introduced the scientific methodology of randomised controlled trials, which seek to completely remove extraneous variables without the researchers having to isolate them. The scientific advantage of randomised experiments is that it completely removes conscious or subconscious bias from the researcher and maximizes external validity [2].

Six prototype armoured vests were engineered, each using different design modifications and various combinations of technical textiles and spacer fabrics to assess which combination if any, would potentially increase airflow between the body and the armour, thus reducing dehydration. Prototypes were tested over a six-week period on sports studies students who exercised in the chamber for one hour at each session, working at 65% intensity in 70% relative humidity. These variables were determined by SESRI as the conditions most likely to mimic the heat dissipation felt by officers on routine, active duty. The prototypes were weighed pre- and post-exercise to measure moisture absorption by the jackets and the subjects were also weighed, pre- and post-exercise. Additional data was collected and measured including urine, temperature, thirst, heart rate and Borg scale data (Borg, 1982). Robust statistical measurements were applied to the data set and used to determine the best combination of design and technical fabrics to be used in the final prototype. The new knowledge was made available to the Company to allow it to embed it into its design strategy and enhance its products.

3.2 Case Study 2: Moulded Thermoplastic Composites for Female Body Contouring

Traditional construction methods of stitching darts into female body armour meant that with over 15 layers of Kevlar needed for each garment, the stitchers in the Company had to sew more than 30 darts into the finished vests, which was not only labour intensive, but additionally had crude results due to the stiff, laminated nature of the material, causing discomfort and reduced aesthetic appeal. Collaborative research between a fashion designer and an engineer set out to investigate whether multiple layers of Kevlar could be moulded three-dimensionally over a double curvature, in one operation to create a more ergonomically pleasing shape for female wearers.

Moulded, thermoplastic composites have superior impact and damage resistance properties, theoretically allowing lighter, protective garments to be manufactured to a nett-shape, thus providing a greater level of comfort for female users. In addition to their superior properties, it was estimated that thermoplastic composite vests could lead to more efficient production times than conventional pre-laminated, stitched products and could potentially make thermoplastic vests cheaper to produce than existing garments. Recyclability properties also had potential to save on waste management costs. Coulter and Archer (2009) explored the development of a process protocol for nett-shape, thermoplastic, Kevlar-reinforced vests. The overall objectives were to design and manufacture a demonstrator component and to develop a manufacturing route for an optimised armour vest for females. The engineer determined variables in thermoplastics and temperature and the fashion designer determined variables in fabric structure and pile, allowing initial tests to be carried out to establish which combinations would positively affect the success of the outcome. The engineering input provided vital knowledge and expertise in thermoplastics, but lacked sensitivity to the anthropometrics of female anatomy. Once the concept of 3D Kevlar moulding was proven to work using a basic, double-curvature, domed template, more accurate data on female anatomy was obtained by the fashion designer using a body scanner at the Health and Rehabilitation Sciences Research Institute (HRSRI) at the University of Ulster. (HRSRI) followed ethical procedures and live subjects were used to create images, from state-of-the-art, 3D imaging technology. Applying knowledge in anthropometrics, the fashion designer extrapolated the data created by HRSRI and developed a blended dataset so that the final torso measurements were more generic, thus ensuring that the finished fit of the moulded Kevlar would span a greater size range of females.

The new knowledge from the dataset was translated by the engineer via CAD CAM into a machined torso in aluminum, which was then used to successfully mould multi-layers of Kevlar on to it in one operation, using thermoplastic techniques. The unique new knowledge was presented to the Company, allowing them to make informed decisions about the innovative development of their products.

4 Managing knowledge in university-led collaboration

The Company partner was keen to build on the new university knowledge to develop strategies to help to survive the ongoing recession. Evidence suggests that organisations surviving the recession are doing so by being innovative in their business models and their approach to design. In addition to strong customer focus, knowledge management provides the key to successful innovation and Egbu et al (1999) contend that collaboration is vital for knowledge management. There are strong synergies between theories of strategic management and knowledge management and understanding their relationship provides a useful structure for understanding the importance of collaborative research partnerships between universities and industry.

Knowledge exchange between companies and universities can take many forms, ranging from collaborative R&D projects to informal agreements undertaken on an ad hoc basis (Cassiman & Veugelers, 2005). The Chesbrough (2003) open innovation model, suggests that companies should use external ideas as well as internal ones to further innovation. Bruce and Morris (1998) agree, contending that companies seek partnerships when their own internal design capabilities become complacent and stale and lack the vision and innovation that external design expertise can provide. Knudsen (2007) concurs with the author, arguing that external collaborators can provide specific, technical knowledge for bespoke projects as in the two outlined case studies in this paper. Harnessing external collaboration can provide companies with a suite of diverse and complementary resources necessary to turn innovative ideas into successful, commercial outputs (Hagedoorn, 1993) and this explains why companies seek to develop sources of knowledge with external partners such as universities, as an effective means of delivering core benefits (Baker & Sinkula, 1999). The specialised support that academic knowledge can provide can be accessed by emerging technologies and state-of-the-art equipment to further their own internal R&D make university partnerships an attractive option to industry (Tidd & Trewhella, 2002). Universities are seen as low-risk sources of innovation that are especially useful for new product development and their research institutes can generate a wealth of knowledge (Brettel and Cleven, 2011). Tijssen (2002) and Narin et al (1997) concur and evidence shows that companies that do not acquire technological knowledge from universities may fall behind with innovation and be less likely to make technological breakthroughs that lead to viable commercial products (Spencer 2003).

The new knowledge that the Company needed could not be achieved with one type of expertise alone, hence the interdisciplinary approach and Jobber (1991) argues that combining research procedures is more useful than one single procedure, providing a more comprehensive analysis of the problem studied. Rhoten and Pfirman (2007) define interdisciplinarity as "the integration or synthesis of two or more disparate disciplines, bodies of knowledge, or modes of thinking to produce a meaning, explanation, or product that is more extensive and powerful than its constituent parts."

5 Drivers for Collaboration between Universities and Industry

Understanding the motivations and processes leading academics to engage in collaborative research and the resultant technological developments provide vital strategic insights for companies, allowing them to develop innovation strategies. Mueller (2007) concurs, contending that entrepreneurship and university–industry relations are vehicles for knowledge flow and thus spur economic growth.

Perkman and Walsh, (2009) devised a classification framework for types of university-industry collaborations which suggested that those focused toward 'ideas testing' are typically low-cost projects initiated by either academics or companies to investigate potentially interesting and commercial ideas, as outlined in the two case studies in this paper. Narin et al (1997) also cites cost effectiveness as a key factor for university-industry engagement. Kabins (2011) suggests that a motivating factor for academics engaging in university-driven collaborations which are aimed at testing ideas, may be the close involvement of public sectors end users and the inspiration for academics becoming involved is the quality of data collected when investigating 'live' problems and genuine needs, whereas companies tend to be more passively engaged and interested solely in the end product and commercial output. Having the MoD as an end user of the Company's products was a strong driver for academic involvement in this project.

It is important to balance some of the reviews that may over-simplify the motivations and execution of interdisciplinary collaboration. There are many drawbacks which need to be given due consideration. Often there are more costs, greater co-ordination requirements and project management challenges. Katz and Martin, (1997) and Nooteboom (2000) caution that costs can escalate due to the cognitive distance between partners. It was established at the outset of this research that costs and logistical factors would not outweigh the benefits of collaboration, however the main challenges would be in understanding the working methodologies and 'languages' of practice from the different disciplines involved.

6 Characteristics of Academic Collaborators

There is limited research data available on the characteristics of individuals who choose to engage in interdisciplinary collaboration. The motivation for some researchers is simply, to learn from distant disciplines of science or because they have identified a specific area of research that requires the input from disparate disciplines, as was the case with this author. They may also be driven by the possibility of future benefits in terms of publications, recognition and further funding opportunities (Melin, 2000). Van RijnSouever and Hessel (2011) and Carayol (2004) define a set of characteristics of researchers engaging in interdisciplinary collaboration. However Rafols and Meyer, (2007) cite consolidating knowledge where problems to be solved are complex and increasing access to funding opportunities as equally valid drivers. Enhancing personal credibility and desire to earn peer recognition are also contributing factors (Whitley 2000).

7 Dynamics and Challenges of Interdisciplinary Collaboration

There are limited examples of successful collaborations between design-based subjects such as fashion and more science-based subjects, such as engineering. One reason for this is perhaps how research is framed and how outcomes are measured and disseminated differently in each discipline. Scientific methodologies rely on defining a set of principles and procedures that are used by researchers to develop questions, collect quantitative data and reach conclusions. However, design-based research relies on strategies of qualitative inquiry and outcomes are often measured in a more ambiguous way, such as user perception and emotional tactility and these metrics do not always sit comfortably within the science domain. These different 'languages' of research can lack commonality and understanding, which can make knowledge difficult to transfer and may inhibit collaborative success. Design- and arts-based research does not always fit in with existing typologies of scientific research and new typologies of qualitative research need to be recognised by scientists to bridge the gap and establish a greater respect for art and design based research (McNiff, 1988). Similarly, designers need to make a culture shift and embrace scientific methodologies. The author contends that it is likely that designers will need to make the greater shift and will have to accept new technology and develop a better understanding of scientific methodologies. Openness to a range of diverse research methodologies, willingness to engage, understand and demonstrate mutual respect for all contributors are required to deliver successful outcomes. This is not always an easy task for scientific, left-brain thinkers who prefer well-structured, well-defined tasks, to open-ended ones. Design processes need to be adaptable and allow for ambiguity and whilst designers' right-brain thinking skills are adept to these ad hoc processes of working, the uncertainty of outcomes can be challenging for engineers and scientists to accept. Fraser (2010) stresses the importance of collaborative researchers being able to embrace both the friction and the fusion that come with intense collaboration.

There are pros and cons regarding case studies and pure statistical methodologies and whilst physical scientists tend to avoid a case study approach, anthropologists consider them an essential tool. A case study may introduce unexpected results, leading to new avenues of research and it is also recognised that in the dissemination of results, case studies provide more interesting themes than purely statistical surveys. While statistics may be interesting to scientists or other academics, well-positioned case studies can give a stronger impact to a wider audience.

8 Conclusion

Within the context of the case studies outlined in this paper, it is concluded that the combination of design- and science-based research succeeded in creating new knowledge, which was successfully transferred to industry. Equally important outcomes to the project were the knowledge exchange and innovative approaches to research and design acquired by the collaborators. The designer clearly had much to learn from scientific approaches and methodologies, including randomized trial experiments and scientific measurement of outcomes. Knowledge was gained of technologies within engineering and rehabilitation sciences and new codes of practice, such as ethical approval were noted. The scientists benefitted greatly from design-led approaches and working creatively, in addition to gaining knowledge of high-performing technical textiles, anthropometrics and most significantly commercial application.

It is anticipated that as more designers embrace technology then more collaboration and innovative knowledge transfer will be possible. Cohen et al. (2002) note that generating scientific knowledge together with the associated benefits that universities can offer is a key foundation of industrial innovation and Schmickl and Kieser (2008) note that interdisciplinary science has a positive effect on knowledge production and innovation.

It is worth noting that, had the project spanned a longer period of time and had a larger budget, there may well have been more challenges for leadership and management within the project.

This interdisciplinary project was initiated and led by a fashion designer. Designers are imaginative experimenters who often take on a ‘cross-pollinator’ role (Kelley, 2004) that allows them to work creatively across many disciplines. The key for a designer always lies in creativity and as a designer from a non-scientific background the author offers a metaphoric ‘creative equation’ as a tool to begin build a common language for scientists and designers. The premise being that the greater the multiplier of creativity, in science-based collaboration, then the greater the likelihood of innovative new knowledge created:

$$\mathbf{(SK+ACM) \times C = INK}$$

where **SK = Scientific Knowledge**
ACM = Appropriate collaborative methodologies
C= Creativity
INK = Innovative new knowledge

Source: Coulter 2011

Acknowledgements:
Dr. Edward Archer, ECRE Engineering Composites , Research Centre, University of Ulster
Dr. Gareth Davison, Sport & Exercise Sciences Research Institute, University of Ulster
Dr. Conor McClean, Sport & Exercise Sciences Research Institute, University of Ulster
Prof. John Winder, Health and Rehabilitation Sciences Research Institute, University of Ulster
Mrs Orlagh Carmody, Head of Design, Global Armour Ltd
Mr Gary Hayes, Sales and Marketing Director, Global Arnour Ltd
Mr Mark Griffiths, Sales Manager, Woven Industrial Solutions, Heathcoat Fabrics, Devon

References

Borg G A (1982) Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise 14:377-381

Baker W E, Sinkula J M (1999) Learning orientation, market orientation, and innovation: Integrating and extending models of organizational performance. Journal of Market Focused Management, 4, 295–308.

Bruce Morris (1998) A comparative study of design professionals. In Management of design alliances: sustaining competitive advantage. M. Bruce and B H Jevnaker (eds). Chichester, John Wiley

Cassiman B Veugelers R (2005) R&D Cooperation between Firms and Universities: Some empirical evidence from Belgium,(pdf) The International Journal of Industrial Organization, 23 (5-6), p. 355-379

Carayol, N Thuc Uyen Nguyen T (2005) "Why do academic scientists engage in interdisciplinary research." Research Evaluation 14(1): 70-79

Cian C, Koulmann N, Barraud P, Raphel C, Jimenez C, Melin B (2000) Influence of variations in body hydration on cognitive function: effect of hyperhydration, heat stress, and exercise-induced dehydration. J Psychophysiology14 :29– 36

Chesbrough H W (2003) The Era of Open Innovation. MIT Sloan Management Review, 44, 35–41.

Cohen W, Levinthal D, Damiel A (1990) Absorptive Capacity: A New Perspective on Learning and Innovation, ASQ, 35, (1990), 128-152, faculty.babson.edu/krollag/org_site/org.../**cohen**_abcap.htm. Accessed 10 January 2012

Cooper R, Press M (2000) The Design Agenda; A guide to Successful Design Management. John Wiley & Sons, UK

Coulter J, Davison G, McCLean C, Carmody O (2009) ''What if?' Research and Innovation by Design. Proceedings from The Senior Staff Conference, University of Ulster

Coulter J. Archer E (2009) ''What if?' Research and Innovation by Design. Proceedings from The Senior Staff Conference, University of Ulster

Daanen H A M, Reffeltrath P A, Koerhuis C L, (2000) Ergonomics of Protective Clothing. In The Netherlands in Intelligent Textiles for Personal Protection and Safety. Jayaraman S et al. (Eds.). IOS Press, Amsterdam

Dalpe, R., DeBresson, C. and Xiaoping, H. (1992). The public sector as first user of innovations, Research Policy, 21, 251-263.

Egbu C O, Sturges J, Bates M (1999) Learning from Knowledge management and trans-organisational innovations in diverse project management environments. In Hughes W(ed), 1th Annual ARCOM Conference, 15-17 September 1999, Liverpool John Moores University. Association of Researchers in Construction management Vol. 1, 95-103

Fraser H (2010) Designing business. New models for success. In Lockwood T (ed) Design thinking: Integrating Innovation customer experience and brand value. Allworth Press, New York

Gopinathan P M, Pichan G, Sharma V M (1988) Role of dehydration in heat stress-induced variations in mental performance. Arch Environ Health 43 :15– 17

Hagedoorn J, Duysters G (2002) External Sources of Innovative Capabilities: The Preferences for Strategic Alliances or Mergers and Acquisitions. Journal of Management Studies, 39, 167–88.

Huxman and Vangen (2005) Managing to collaborate. Theory and practice of collaborative advantage. Routhledge, London

Jobber D (1991) Choosing a survey method in management research. In Smith N C and Dainty P (eds). The Management research handbooks. Routledge, London

Kabins S (2011) Evaluating outcomes of different types of university-industry collaboration in com-

puter science. Conference proceedings Academy of Management (AOM) Conference 2011
Katz J S, Martin B R (1997) What is research collaboration? Research Policy 26, 1–18.
Kelley T, Littman J (2004) The Ten Faces of Innovation; Strategies for heightening Creativity. Profile Books
Knudsen M P (2007) The Relative Importance of Interfirm Relationships and Knowledge Transfer for New Product Development Success. Journal of Product Innovation Management, 24, 117–38.
Lieberman H R (2007) Hydration and Cognition: A Critical Review and Recommendations for Future Research. J Am Coll Nutr October, vol. 26 no. suppl 5 555S-561S
McNiff S (1988) Arts Based Research Arts Based research – Jessica Kingsley ltd. London
Melin, G., 2000. Pragmatism and self-organization – research collaboration on the individual level. Research Policy 29 (January (1)), 31–40.
Mellis W (2003) Partnering with Customers. In: Jolly A (ed) Innovation; Harnessing Creativity for Business Growth. Kogan Page, London
Mueller P (2007) Exploring the knowledge filter: How entrepreneurship and university–industry relationships drive economic growth. Research Policy Volume 35, Issue 10, December 2006, Pages 1499–1508. Elsevier
Narin F, Hamilton K S, Olivastro D (1997) The Increasing Linkage between US Technology and Public Science. Research Policy, 26, 317–30.
Nooteboom B, (2000) Learning by interaction: absorptive capacity, cognitive distance and governance. Journal of Management and Governance 4, 69–92.
Perkmann M, Walsh K, University-industry relationships and open innovation: Towards a research agenda (review article), International Journal of Management Reviews, 2007, Vol:9, Pages:259-280
Perkmann M, Walsh K (2007). How firms source knowledge from universities: partnerships versus contracting (forthcoming). In Bessant J, Venables T. (eds), Creating Wealth from Knowledge. Cheltenham: Edward Elgar.
Press M, Cooper R (2005) The Design Experience, The Role of Design and Designers in the Twenty First Century. Ashgate Publishing Limited, Hampshire, England
Rafols I, Meyer M (2007) How cross-disciplinary is bionanotechnology? Explorations in the specialty of molecular motors. Scientometrics 70 (3), 633–650.
Rhoten D, Pfirman S (2007) Women in interdisciplinary science: exploring preferences and consequences. Research Policy 36 (February (1)), 56–75.
Rixon D (2003) Strategic Commitment- The Foundation Stone for Innovation. In: Jolly A (ed) Innovation; Harnessing Creativity for Business Growth. Kogan Page, London
Schmickl C, Kieser A (2008) How much do specialists have to learn from each other when they jointly develop radical product innovations? Research Policy, Volume 37, Issue 3, April 2008, Pages 473-491. Elsevier
Spencer J W (2001) How Relevant is University-Based Scientific Research to Private High-Technology Firms? A United States–Japan Comparison. Academy of Management Journal, 44,432–40.
Tidd, J, Trewhella M J (2002) Organizational and Technological Antecedents for Knowledge Acquisition and Learning. R&D Management, 27, 359–75.
van Rijnsoever F J, Hessels L K (2011) Factors associated with disciplinary and interdisciplinary research collaboration. Research Policy Volume 40, 2011, Pages 463-472.
Whitley R (2000) The Intellectual and Social Organization of the Sciences, 2nd edition. Oxford University Press, Oxford.

[1] http://www.ktponline.org.uk/strategy/
[2] http://www.experiment-resources.com/randomized-controlled-trials.html#ixzz1moF2sRxd