A NEW UNIVERSITY-INDUSTRY COLLABORATION MODEL TO TRANSFORM AUSTRALIAN MANUFACTURING SMES

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ABSTRACT:

The spirit of Australian manufacturing was established by a need and desire to innovate at a technical level; nourished by a culture of making, vitalised by our geographic remoteness. Today, Australia finds that it cannot compete in labour-intensive, low-skilled manufacturing and must develop design-driven innovation strategies to survive. Through university-industry collaboration (UIC) manufacturing can be supported in this transition. UIC is complex due to differing incentives and orientation between the goals of industry and university research. Literature analysis on UIC research and of the challenges facing Australian manufacturing combines with a new Integrated Product Design program at the University of Technology Sydney to form the basis of a new UIC model to support local manufacturing industry. The Integrated Product Design Research (ipd-r) UIC model proposes to reduce the barriers to successful UIC by incorporating student projects that appropriately stimulate a longer term UIC engagement necessary for the creation of important strategic innovation integration and new knowledge outcomes. Additionally, we believe that the ipd-r UIC model with its focus on practice-based research is more conducive to the particular attitudes and spirit of Australian manufacturing.

Keywords: University-industry collaboration, design-driven innovation, practice-based research, Australian SMEs.

1. INTRODUCTION

The making of objects in Australia has a history that dates back thousands of years, indigenous Australians fashioned a vast array of objects such as spears, boomerangs and fishing nets for hunting and musical instruments for ceremonial use. European settlement that occurred at the end of the 18th century brought with it a different form of making, basic manufacturing was first recorded soon after settlement with the making of bricks which satisfied the need for construction materials that were expensive and time consuming to transport (Carroll 1987). Australia’s geographic remoteness afforded the country's early manufacturing endeavours a form of natural protection, however this advantage was set against a small and narrow market and a shortage of skills and equipment. The mid-19th century saw the gold rush increase population and with this an increased demand for goods and an expanded workforce.

2. AUSTRALIAN MANUFACTURING

Protectionist policies were introduced, stimulating manufacturing into the 20th century and the First and Second World War further increased manufacturing in Australia (Norman 1971; Carroll 1987) as the nation set itself up for defence. The second half of the 20th century saw large numbers of skilled and non-skilled workers emigrate to Australia which further increased demand for products and services. Government policy continued to support manufacturing through tariff protection, import licensing, incentives, subsidies and tax rebates (Norman 1971) and by the late 1950's manufacturing accounted for 29% of Australian GDP (Milne 2010). Government intervention contributed to the decline in manufacturing in the late 20th century by (among other decisions) shifting economic reliance to mining and the supply of resources to emerging industrial nations (Milne 2010). These factors along with; inferior productivity, a 25% reduction in tariffs, increase in labour costs (Eslake 2007) and a shifting of strategic responsibilities to foreign investors impacted the Australian manufacturing sector to the point where today it accounts for less than 10% of Australian GDP. Despite these challenges, the 21st century has seen the manufacturing industry diversify into a wide variety of goods to become in 2010-11 the third largest value adder in the Australian economy (ABS 2013). The sector has evolved from having a once narrow and limited product offering to a broad and diverse industry, from low value added commodity products at one end to high value-added products at the other (Future Manufacturing 2011). These figures along with the disruptive path of development of the national manufacturing sector may be explained by the large proportion of manufacturing SMEs in Australia. Currently, SMEs make up almost 88% of the manufacturing industry in Australia, providing a range of opportunities and challenges (Doherty, Matthews, Wrigley and Buculo 2013). It is noted that for advanced economies manufacturing accounts for a large portion of business R&D, contributes to society's scientific knowledge, is integral to development of new technologies and national security and defence (Benedettini, Clegg, Kafouros and Neely 2010). Economically, manufacturing is an important contributor to the Australian economy (Doherty, Matthews, Wrigley and Buculo 2013) and is responsible for a quarter of research and development among businesses(Future Manufacturing Trends 2011). A report on the future of manufacturing in the UK highlights an important distinction between manufacturing and production, clarifying the broader activities of manufacturing that involve R&D, design, marketing, distribution service and support (Benedettini, Clegg, Kafouros and Neely 2010). The report (2010) goes on to argue that the term production (the task of transforming materials into goods) is used interchangeably with manufacturing highlighting the issue of perceiving manufacturing as having a limited role and responsibility in the social context. A statistic quoted in a report by Engineers Australia (2009) states that however, almost two-thirds of Australian businesses are classified as "non-innovators" by the ABS, meaning that businesses in this category had not introduced any new products, services, operational or organisational processes in the previous two years (Engineers

Australia 2009) suggesting that the perception of manufacturing as solely production may be prevalent in Australian manufacturing industry as well.

3. AUSTRALIAN MANUFACTURING SMES

Manufacturers in Australia have extensive experience in small volume manufacturing which was once seen as a negative and a weakness. This is now viewed as being flexible and responsive, able to supply low volume to a high range of customers, an opportunity to operate in contrast to high volume economies like China and the USA. This differentiation will establish a competitive advantage that can be exploited (Future Manufacturing Trends 2011). Australian SMEs are recognised as having the potential of performing a pivotal role in the knowledge economy (Viet and Valadkhani 2014). However, because SME's account for as much as 88% of the manufacturing industry, the wider problems for Australian manufacturing to gain market share and remain competitive may be amplified (Doherty, Matthews, Wrigley and Buculo 2013); as it has been noted that SMEs typically do not have the competency or resources required for design-driven innovation (van der Bijl-Brouwer and Buculo 2014). Design-driven innovation enables a 'whole-firm' approach to design beyond the product offering alone and informs the systems and strategies necessary to adjust and link business systems, products and services (Bucolo, Wrigley and Matthews 2012). It has been noted by Engineers Australia (2009) that a key issue in increasing R&D in Australia is that many SMEs do not undertake R&D activities or are unable to commercialise R&D outcomes due to lack of information and skills to invest in R&D correctly. Design support for SMEs as a strategic activity should raise local identity, develop regional talents and adopt the ability to "think globally and act locally". One-on-one support with SMEs have shown to directly lead to tangible outcomes that have immediate business impact (Cawood, Lewis and Raulik 2004). Poor design integration in Australian SMEs seem related to the risk adverse nature of SME manufacturing businesses, particularly when design-driven innovation requires a 'whole firm' approach. A study that investigated the integration of design-driven innovation with a small manufacturer by Doherty, Wrigley, Matthews and Buculo (2013) identified three challenges in the utilisation of design in SMEs:

1. Managing expectations. Design innovation is more than simply improving the visual appeal of existing products but as a wider strategic function.
2. Conveying relevance and potential. Design, as a strategic function within a company, means that the design-led initiatives of other departments must be supported. The development of design strategy must involve not only the director and designers but other department representatives.
3. Risk adverse culture. Addressing a risk adverse culture which is reactive rather than proactive by translating design innovation meaning across all facets of the organisation and bridge operational and strategic activities to hone the company's core value proposition.

The research demonstrates the importance of the development of a design culture within the company rather than seeing design purely as new product development that can be outsourced to an external consultancy. Design, integrated throughout the organisation can transform the way products, services, processes and strategies are developed (Brown 2009). SMEs require support to integrate design innovation at a strategic level and requires designers be brought in at the early stages to service the shift and to manage development of concepts as the business case develops (Chhatpar 2007). Design-driven innovation refers to a set of methods that allow evaluation of the product and service concept within an organisation from multiple perspectives as a function of transitioning to a knowledge economy (Wrigley and Buculo 2011). Identified as a vital strategic business resource, design-driven innovation aims at changing the emotional and symbolic meanings of products through a deeper understanding of broader societal, cultural and technological changes 'pushed' by an organisation's vision rather than an a reliance on conventional marketing tools (Verganti 2009). Based on case studies, Australian manufacturing SMEs are arguably still focused on the industrial economy paradigm that seeks value through cost-reduction and incremental changes in product designs (Doherty, Matthews, Wrigley and Buculo 2013). The support of design-driven innovation in SMEs, given the objective of addressing sociocultural concerns as a basis for innovation, may have the potential to carry SMEs beyond the knowledge economy and into, what was first described by Peter Drucker (1981) as the transformational economy paradigm. The transformational economy is defined by industry, government and academia collaborating to create socially and ecologically sustainable designs that generate shared value across public and private networks (Gardien, Djajadiningrat, Hummels and Brombacher 2014).

4. UIC

External partnering between manufacturing SMEs and external research units can enhance innovation performance (Malik and Wei 2011, Lasagni 2012). However, research on university-industry collaboration (UIC) in Australia indicates that there has been a relatively 'low level of collaboration between SMEs and universities and other publicly funded organisations' (Engineers Australia 2009) and that barriers to innovation need to be improved. Further, it has been shown that Australia performs poorly in translating research into commercial outcomes due to a series of factors that include gaps in organisational leadership and knowledge transfer (Bucolo, Wrigley and Matthews 2012). UIC collaboration is considered both beneficial and necessary for improving the competitive advantage of SMEs, as funding through the Australian Government's Industry Growth Centre Program has been developed to encourage collaboration and commercialisation of new products (Dept. of Industry and Science 2015). Advanced manufacturing is one of five growth centres in the program and the category through which funding is made available for product innovation. The aims of boosting competitive advantage of the nation's manufacturing SMEs requires new models of UIC collaboration to be developed. A key factor in supporting the integration of design-driven innovation at a strategic level in SMEs involves knowledge transfer. Research suggests that learning how to translate data into value propositions and the development of an innovation strategy and to establish trust between the SME and the research unit may only be achievable through extended periods of engagement (van der Bijl-

Brouwer and Buculo 2014). Additionally, product design develops, understanding of the broader social responsibility associated with the creation of future products, as product ecology, is necessary and reliant on experimental prototyping and longer-term research activity (Forlizzi 2008) marking a cultural shift in SME R&D practice.

5. IPD-R UNIT AND THE IPD COURSE

The tools of design research and design ability are converging. Koskinen, Zimmerman, Binder, Redström and Wensveen (2011) note the sense for the conduct of research to be built on the strengths of the academic team and suggests that the work stay close to the issues and concerns of the location of the research unit, broadly acknowledging that design research is highly contextualised and situation specific. The academic members of the ipd-r unit are all engaged in practice, with up-to-date design abilities in order to conduct forms of practice-based research (Walden, Lie, Pandolfo and Lockhart 2015). A practice-based research approach incorporates prototyping which offers the opportunity to experiment and explore with stakeholders (Brown 2009). The making and prototyping of designs requires collective design ability and allows for research into ways of integrating design outcomes with new manufacturing systems. Product design concepts must move beyond speculative ideals and be detailed concurrently with the design of the system. As a central tool of research, prototyping along with other practical design skills has been recognised as a way to connect between fields of knowledge (Stappers 2006), in this case between the product innovation and the manufacturing system or strategy. Additionally, these knowledge connections may develop into theory, where the prototypes embody “physical hypotheses” (Overbeek, Wensveen and Hummels 2006) that serve to test, challenge and perhaps verify appropriate connections between product designs and manufacturing systems. The ipd-r unit engages in what Koskinen, Zimmerman, Binder, Redström and Wensveen (2011) might describe as constructive design (lab) research though the knowledge enquiry is positioned closer to local industry concerns in the pursuit of future-focused knowledge outcomes that are relatable to the industry partner. One of the core activities of the ipd-r Research Unit is to develop models for UIC partnerships with local manufacturing SMEs in response to our University’s wider strategic goal to manage complex driven processes beyond the discipline. Knowledge development and practices of the research unit directly inform the course curriculum with an emphasis on practice-orientated learning to inform contemporary design practice through design-driven innovation (Lie and Walden 2015). Projects conducted by students in the IPD course are geared toward innovation for the sustainability of economic, ecological and social values (Teixeria 2010) by modern modes of commercialisation and advanced manufacture. Student projects are delivered without methodological prescription (Goldschmidt and Rodgers 2013) and students are supported in the design of methodology and research aptitude in order to frame ill-defined, complex problems, manage abduction problem reasoning (Dorst 2015) to contextualise and pursue responsible opportunities for design intervention. Students are guided through constraint and priority of the features of their concepts and given broader scope for exploration. Innovation of fabrication processes is acceptable and can lead to the generation of new forms. The course embraces the artistry of design and acknowledges the designers own culture in the context of design-driven innovation and its means of knowledge-based exploration to identify new product meanings and languages (Verganti 2008). More advanced student projects may use metaphor to challenge identification and desirability factors of products beyond aesthetics and that respond to the connection between the source of innovation, user experience and societal trends (Buchanan 2001). We encourage students to go beyond the conventions of mass-manufacturing, business, marketing and branding while maintaining an emphasis on the importance of prototyping, design skills and making as methods of research enquiry. The IPD program at UTS has a long history of exposing students to real-world practice through industry projects - an approach that supports student learning. Though determined to maintain this practice, we find that a more sophisticated relationship between the industry partner (the manufacturing SME) and the student project must evolve according to new student learning objectives that reflect modern design practice and how innovation is defined. A way forward is to have student projects informed by a strategic UIC partnership.

6. AN INTEGRATED UIC

Advanced economies cannot rely on the service industry alone. Manufacturing is an important sector in terms of developing a society's technical competency and new knowledge through the creation of commercialisable outcomes. The growth and recognition of the maker movement globally and in Australia is credited as being a rebirth of manufacturing with its focus on tangible product innovation and networked processes (Deloitte 2014). The identification and development of the connection between the methods and goals of design research and design practice toward knowledge creation, through practice-based research, together with the recognition of the importance of the academic design practitioner (Walden, Lie, Pandolfo and Lockhart 2015); supports a refocus on product innovation to advance the competitive advantage of our large manufacturing SME sector. By developing UIC partnerships with manufacturing SMEs that utilise the knowledge creation opportunities through design-driven innovation product development, we can engage with Australian manufacturers in the spirit of making and prototyping that they can immediately identify with. Over the longer-term it may become feasible to generate important knowledge outcomes that serve to not only define strategic directions shaped by the identity of the industry partner, but also provide models for wider application in the advance of an innovation economy. Research indicates that while UIC with Australian manufacturing SMEs can facilitate the cultural shift toward a company vision, general awareness of the integration of design and practice, and knowledge in strategic development (Krabye, Matthews, Wrigley and Buculo 2013); barriers continue to exist. University-industry collaboration is complex due to the objective to develop and change the organisation culturally. Identified barriers are associated with facilitating knowledge exchange and learning. Bruneel, D'Este and Salter (2010) described the barriers to UIC to broadly include (1) differences in incentives and orientation whereby universities tend to be orientated toward 'pure science' and long-term orientation of research compared to the urgency of implementable industry research; and (2) conflicts over Intellectual Property (IP) and administrative dealings. This paper will not address IP directly but focus on point (1) noted above. We argue that through strategically configuring the objectives of the ipd-r Research Unit and the UG (undergraduate) curriculum to be unified by a focus on the development of design-driven innovation in physical product design, practice-based research and prototyping, UIC partnerships can be formed with Australian SMEs that are compatible with their view of innovation culturally and overcome the barriers of UIC. The study by Bruneel, D'Este and Salter (2010) suggests that over time a mutual understanding about expectations and work practice develops. Routines learnt through conducting joint research also lowers barriers related to the long-term nature of university research. Therefore, a UIC that can address both short-term goals (through low level projects) and long-term strategic goals (through high level projects) of both partners collectively, needs to be established. The study by Bruneel et al. (2010) also indicates that as well as collaboration experience, a breadth of interactions further assist in overcoming barriers to UIC. Additionally, to overcome the disadvantages that SMEs typically encounter in addressing knowledge from external sources may depend on stimulation provided by the context of the collaboration to encourage a firm to interact with innovation (Lasagni 2012). Based on these implications, a UIC that has multiple, stimulating engagements across a longer span of time so that the UIC relationship can develop fully, seems to be important. A study of SME technology roadmapping in Korea found that external support engagements that focus on future planning for 2-3 year term is more practically useful for SMEs (Jun, Seo and Son 2013). The development of the IPD program incorporates design-driven innovation to deeply explore the socio-cultural and technological implications in product designs through prototyping and flexible methodologies to frame appropriately open, complex and networked problems through practice-based research. The shaping of all elements of the program is directly informed by the activities of the members of ipd-r unit who seek to develop new knowledge connections between the tools of design research and design practice as academic design practitioners (Walden, Lie, Pandolfo and Lockhart 2015). The nature of this connection presents an opportunity to expand upon the way we conduct UIC with our manufacturing SME partners.

7. IPD-R UIC MODEL

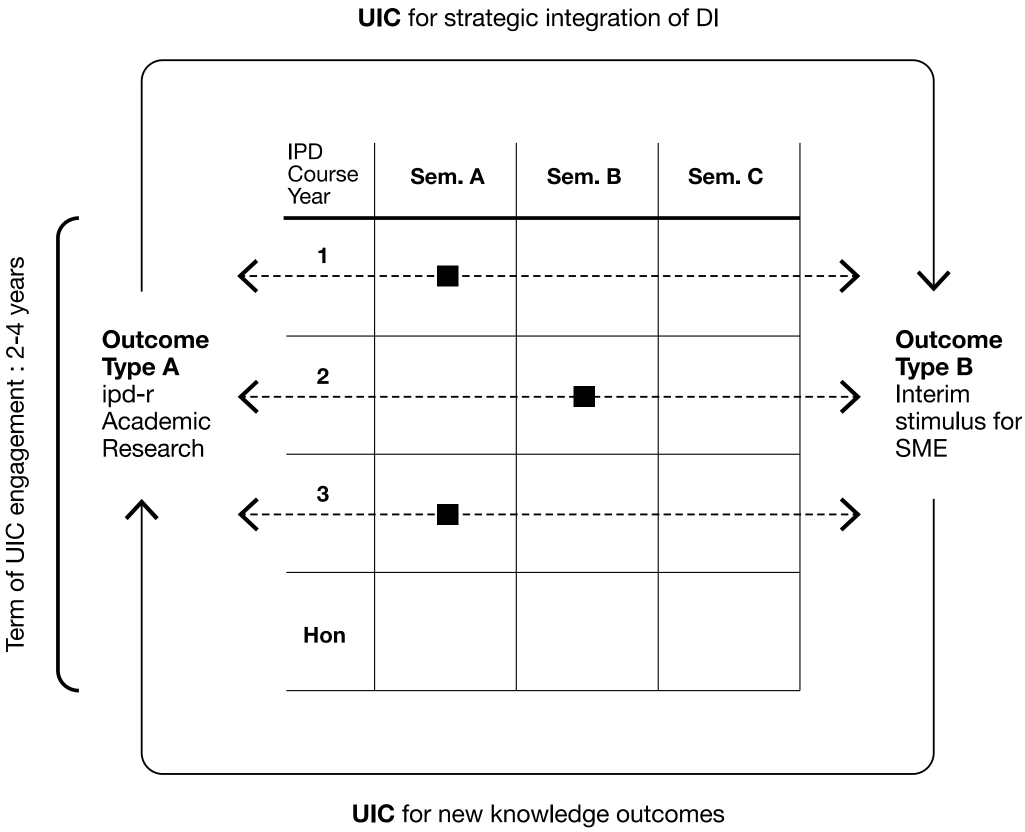

Figure 1: ipd-r UIC model

The proposed IPD-R UIC model (Fig. 1) involves the collaboration between an SME and an academic research unit. The strategy could be adapted to a variety of academic fields and businesses, however, the specific nature of this UIC centers around SME's that either manufacture themselves or outsource the manufacturing of proprietary goods. The academic field is one associated with the design, development and manufacturing of new products and/or services. This method has been developed to enable a two pronged approach with utilization of both low level and high level projects. Low level projects address short term knowledge enquiry to compliment high level projects that investigate solutions for long term strategies. Low level projects are designed to stimulate engagement with the SME and may offer implementable outcomes for short-term application. The stakeholders central to this method include academic practitioners from the academic research unit, university students and employees of the SME. The low level projects are shorter in duration and involve the participation of undergraduate students working on appropriately framed, speculative design projects supervised by the academic practitioners. The objective of the low level project is to establish an awareness of the SME's business to both the students and academic practitioners, quickly establish a working relationship between the three stakeholders, expose the students to the process of working with industry and provide the SME with a diverse range of innovative solutions. These low level projects serve to amplify the practice-based research enquiry (results interpretable through the collaborative evaluation by academic and SME members) and to encourage ongoing engagement with the SME as we seek to extend the partnership over 2-3 years. The high level project which is both managed and worked on by the academic practitioners, it is a more rigorous, complex and time consuming undertaking. The objective of the high-level project is to establish the notion of design-driven innovation in terms relatable to the SME, identify long term solutions and formulate subsequent project themes. Both the low and high level projects run concurrently, this serves to embed a period of intense engagement particularly with the university partner which will facilitate cross pollination between projects. Operating low and high level projects will enable a diverse range of participants the possibility to contribute and it will allow the project the opportunity to fluctuate between moments of intense activity and moments of deep reflection. The two types of projects are important, the low level project has an element of speculation but is also very much about addressing short-term needs. This scenario is perfectly suited to student projects which require particular skills and learning to be incorporated into each learning exercise. As an example, UTS has previously worked with Australian sunglasses (SME) manufacturer Glarce. They have expressed interest in investigating new forms. As part of our UIC partnership with Glarce, one form of short term project that we might deliver to students may be to investigate alternative ways to articulate the joint between two forms using hybrid / advanced manufacturing without specifying that it ought to be for sunglasses. As part of framing the openness of this brief they would be required to research an appropriate socio-cultural and technological circumstance for design intervention. This focuses the project around a very specific issue, it addresses a very real need and for the student there is important learning around a well-known mechanical principle. The low level project is about addressing the SME's short term needs, however it also refers to the shorter duration of the project, and importantly, this enables multiple projects to be conducted at the same time as the high level project. One benefit to operating multiple low level projects is that the SME receives outcomes at regular intervals, satisfying an important aspect of this method. Unlike big business which has a history of engaging with research and importantly the resources that allows them, SME's are challenged by their size and lack of available resources and are therefore very cautious about entering into speculative ventures. Providing the SME with regular feedback via the outcomes of the low level projects will appease their need for outcomes as well as feed the high-level project, guiding it along its natural path. The philosophy here is that the SME is more likely to remain engaged with a high level project if there are incentives along the way that placate their pragmatic needs and facilitate their engagement with the academic staff on the development of deeper strategic goals through the high-level project. Another feature of the low level project is the involvement with students. A cohort of students varies in size and the IPD program at UTS has numbers ranging between 30 and 110 students, depending on year and subject. The UTS IPD experience with past industry projects has shown that when there is a large number of student projects there is a very high probability that numerous student solutions will be appealing to the SME. This becomes tangible proof of the value in the collaboration, the SME becomes inspired by the fresh perspective and new ideas, which is often more successful as a catalyst for internal discussions within the SME rather than an outright implementable solution. It is important to provide positive interim results to the

SME as it serves to maintain enthusiasm and support for the high level project. The focus of the high level project is about sustainability and long term strategies. It is less visually appealing but more substantial and arguably more important. The high level project challenges the SME on account of its speculative nature which implies risk, the low level projects reflects a practice they are familiar with, whereas the high level project represents the unknown, both in practice and in outcome. We consider the collaborative design of low level projects and collaborative evaluation of low level project outcomes to act as a vehicle for learning and knowledge transfer within the UIC partnership for the benefit of longer term engagement and shared development of higher strategic goals.

8. CONCLUSION

The ipd-r UIC model acknowledges the need for a longer term engagement with the manufacturing SME partner and the importance of stimulating engagement to develop strategic goals and new knowledge outcomes, by integrating short term student projects. The connection between the knowledge directives and research practice of the ipd-r unit and support of practice-based research enquiry through course subjects enables both the academics and students in the program to contribute to the UIC relationship, thereby expanding the value of the partnership. The significance of the model can be summarised as follows:

1. The SME attains outcomes for short and long term goals concurrently, exposure to engagement with a research focused project and a strategy to deal with uncertain future challenges. In-built stimulus offered by student projects and a practice-based approach to knowledge development acknowledges the spirit and heritage of Australian manufacturing and product development. Ultimately, a closer engagement with the SME that enables a truly collaborative UIC is more respectful.
2. The ipd-r academic practitioners can study the application and the integration of the tools of research and the tools of practice to generate new knowledge outcomes through cooperatively conducted research and cooperatively developed knowledge. The model sustains the development of pedagogies for passing on local knowledge and traditions through making for innovation.
3. Each of these results (above) can be managed for mutual benefit and be supported by government funding thereby relaxing the constraints of budget, finance or market pressures.

Students continue to be exposed to industry practice and learn about the application of research in practice to develop design competency. Supported by design-driven innovation theory in the establishment of appropriately ‘open’ project guidelines enables exploration of tacit knowledge to generate meaning change innovations.

9. DISCUSSION

The ipd-r UIC model describes how the relationship between research, teaching and industry can be combined for sustainable mutual advantage. The model also describes the integration of design-driven innovation and academic design practice. However, there must be a broad direction via which to channel the development of the SME partner. A report by Roy Green, Dean of Business at UTS (Green and Roos 2012) discusses a number of ways that manufacturing SMEs can compete in high-cost environments. The report cites research from Sweden that details a taxonomy of manufacturing micro, small and medium enterprises (MSMEs) based on 186 Swedish manufactures. These are: *technocrats* (high innovation, poor marketing), *conservatives* (non-entrepreneurial, simple products), *marketeers* (low innovation, high marketing), *craftsmen* (e.g. makers), *ikeas* (low-cost products, very innovative, skilled marketers) and *nomads* (below average resources and capabilities, non-innovative, move from market to market). Green states that from a policy perspective, those with the highest 'survivability potential' in Australia are: *technocrats*, *marketeers* and *ikeas*. Using the descriptions above, Australian manufacturing SMEs are probably *conservatives* and *craftsmen* and must grow (transition) into *technocrats*, *marketeers* or *ikeas*. Green states the following characteristics of successful SMEs:

- Globalization
- High performance
- High quality
- Product-Service-Systems
- Depth
- Knowledgeable
- Focus
- Risk reducing innovation partnerships
- Integrated innovation
- Closeness to customer
- Decentralization
- Globalization
- Entrepreneurial leadership

The ipd-r UIC model seeks to support the creation of knowledge, develop innovation beyond product offerings and offer strategic future-proofing by investigating new technologies and establish cultural relevancy (think global - act local). The report by Green and Roos, provides helpful guidelines for the implementation and initiation of the ipd-r UIC model and a reliable starting point for engagement with industry partners.

REFERENCES:

ABS (2013, 27 May 2014) "8155.0 - Australian Industry, 2011-12", Retrieved 29 September, 2015, from http://www.abs.gov.au/ausstats/abs@.nsf/Products/815711FE2B60DEB3CA257B820017A98B?opendocument.

Green and Roos 2012 Australia’s Manufacturing Future, Discussion paper prepared for the Prime Minister’s Manufacturing Taskforce

Benedettini, Clegg, Kafouros and Neely (2010) The ten myths of manufacturing, Advanced Institute of Management research, London

Brown (2009) Change by design, New York: HarperCollins Publishers

Buchanan (2001) Design research and the new learning, Design Issues, 17(4), 3--23.

Bucolo, Wrigley and Matthews (2012) Gaps in organizational leadership: linking strategic and operational activities through design-led propositions. Design Management Journal, 7(1), 18-28

Bruneel, D’Este and Salter (2010)Investigating the factors that diminish the barriers to university-industry collaboration, Journal of Research Policy

Carroll (1987) Australian Made: Success Stories in Australian Manufacturing since 1937. Parkville, Victoria, Institution of Production Engineers Australian Council.

Cawood, Lewis and Raulik (2004) 'International Perspectives on Design Support for SMEs', Design Management Review, vol. 15, no. 4, pp. 71-6.

Chhatpar (2007) Innovative faster by melting design and strategy, Harvard Business Review, September: 1-2.

Deloitte (2014) Product innovation in a hyper connected world: The Australian maker movement, Deloitte Touche Tohmatsu Limited, Australia

Doherty, Matthews, Wrigley and Buculo (2013) Early challenges of shifting and Australian manufacturer’s utilisation of design, Proceedings of Design Management Symposium (TIDMS) 2013, IEEE, Tsinghua International, pp. 259-267

Future Manufacturing (2011) Trends in manufacturing to 2020: A foresighting discussion paper, Department of Innovation, Science and Research. Canberra.

Dorst (2015) Frame innovation: Create new thinking by design, MIT Press

Drucker 1981 Toward the next economies and other essays, New York, Harper and Row

Engineers Australia (2009) Engineering the future of Australian manufacturing, Institution of Engineers, Australia

Eslake (2007) An introduction to the Australian economy, Encyclopedia Americana,

Forlizzi (2008) The product ecology: Understanding social product use and supporting design culture, International Journal of Design, 2(1), 11--20.

Gardien, Djajadiningrat, Hummels and Brombacher (2014) Changing your hammer: the implications of paradigmatic innovation for design practice, International Journal of Design, Vol. 8, No.2

Goldschmidt and Rogers (2013) The design thinking approaches of three different groups of designers based on self--reports, Design Studies, 34(4), 454-471.

Jun, Seo and Son (2013) A study of the SME Technology Roadmapping Program to strengthen the R&D planning capability of Korean SMEs, Technological Forecasting and Social Change, vol. 80, no. 5, pp. 1002-14.

Koskinen, Zimmerman, Binder, Redström and Wensveen (2011)Design research through practice: From the lab, field and showroom, Morgan Kaufmann, MA.

Krabye, Matthews, Wrigley and Buculo (2013) From production to purpose: Using design led innovation to build strategic potential in a family-owned SME, Proceedings of Design Management Symposium (TIDMS) 2013, IEEE, Tsinghua International, pp. 37-46

Lasagni (2012) How Can External Relationships Enhance Innovation in SMEs? New Evidence for Europe', Journal of Small Business Management, vol. 50, no. 2, pp. 310-39.

Lie and Walden (2015) Evolving a university product design program: an approach to contemporary design practice. Tenz conference New Zealand, September.

Malik and Wei (2011) How external partnering enhances innovation: evidence from Chinese technology-based SMEs, Technology Analysis & Strategic Management, vol. 23, no. 4, pp. 401-13.

Milne 2010 http://www.ausinnovation.org/publications/vision-2020/advancing-australia/manufacturing-in-australia-does-it-have-a-future.html, accessed October 12, 2015

Norman, (1971). Manufacturing Industry in Australia. Sydney, Australian Industries Development Association.

Overbeek, Wensveen and Hummels (2006) Design research: Generating knowledge through doing, In Swiss design network. Drawing new territories. state of the art and perspectives. Third symposium of design research. 17-18 Nov., Geneva: Swiss Design Network.

Stappers (2006) Designing as part of research, In R. van der Lugt & P. J. Stappers (Eds.), Design and the growth of knowledge, Nov. 10, 2005, Delft, the Netherlands: Delft University of Technology, Faculty of Industrial Design Engineering.

Teixeira (2010) The entrepreneurial design curriculum: Design-based learning for knowledge--based economies, Design Studies, 31(4), 411-418.

Van der Bijl-Brouwer and Buculo 2014 'The learning needs of small and medium-sized enterprises for design led innovation', Proceedings of DRS2014: Design's big debates, Pushing the boundaries of design research, DRS2014, Design Research Society, Umeå, Sweden, pp. 1288-1300

Verganti (2008) Design, Meanings, and Radical Innovation: A Metamodel and Research Agenda, The journal of product innovation management, 25(5), pp. 436-456

Verganti (2009) Design-Driven Innovation: Changing the rules of competition by radically innovating what things mean, Harvard Business Press, Boston

Viet and Valadkhani (2014) Are exporting manufacturing SMEs more efficient than non-exporting ones? Evidence from Australia's business longitudinal database, Economic Analysis and Policy, no. 44, pp310-317

Walden, Lie, Pandolfo and Lockhart (2015) The academic design practitioner', Paper presented at the Creative Practices Conference 2015 : Making Research / Research Making, Aarhus, Denmark, 10-12 September.

Wrigley and Buculo (2011) Teaching design led innovation: The future of industrial design, Design Principles and Practices: An International Journal, vol. 5, no. 2, pp. 231-239