# Research-led practice in design research used to best demonstrate design theories

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## Abstract

There is contention in the design research community surrounding the legitimacy of industrial design practice used in design research in academia. This study claims that research-led practice in design research within the context of universities through industry-sponsored projects is deserving of scholarly recognition. It can be argued that research-led practice in design research provides a platform for demonstrating the applicability of design theories in practice. Design practice is inspired and directed by research where concepts generated through industrial design practice provide evidence that research-led industrial design practice has the ability to generate a new body of knowledge. It is the research that informs decisions concerning the design process; and by default informing practice of 'research-led industrial design practice'. To substantiate this, two research-led industrial design practice case studies from Swinburne University of Technology, Melbourne, Australia are highlighted to show how design theories are used in practice to benefit industries separate to academic environments.

### Keywords

Academic research; Case studies; Industrial design; Industry; Research-led practice;

### Introduction

Summarised by the International Council of Societies of Industrial Design (ICSID, 2003, as cited in Yang, You & Chen, 2005), industrial design education programs should educate competence in; generic attributes such as problem solving, communication skills and remain adaptable to social changes; specific industrial design skills and knowledge including design thinking, the design process, design methodologies, manufacturing processes and materials, design management, environmental awareness and prototyping skills and; knowledge integration through design and system implementation (p. 158). Additionally, Ho et. al. (1997, as cited in Yang, You & Chen, 2005) divides industrial design practice into four stages: planning, designing, prototyping and engineering (p. 159). While these examples are of industrial design education and competency, they relate to learning practice, which is useful to determine the skills and knowledge acquired to conduct research-led practice. As emphasised by Koskinen, Zimmerman, Binder, Redstrom and Wensveen (2011) "design practice provides methods" (p. 23) and in particular when designing with specific materials — as demonstrated in the two case studies described in this paper — research methods such as prototyping or general experiments with the material is a valuable way of gaining knowledge and research data associated with a specific design and user testing.

The activity of developing commercial products through industrial design practice has been around for centuries, emerging from the industrial revolution. The ability to categorise this 'activity' as design research and generate research funding to a university is relatively new. The 1990's and 2000's saw the growth of 'generative' research methods that put design practice at the core of the research process (Koskinen et al., 2011, p. 23). However, these methods did not always translate into a commercially viable product outcome. Dorst (2008) argues that design research should refocus its attention and enrich academic design research by working on a deep and systematic understanding of the 'design object', the 'designer' and the 'design context'. This statement is used to legitimise the intentions of this study by promoting the designer, the design context and most importantly the physical manifestations of research-led practice in scholarly design research, with a direct focus on a new contribution to knowledge that is accessible to industry.

From an academic standpoint and as research active members of staff within higher education in industrial design, it serves as a base platform to do both – develop commercial products while satisfying research obligations of a university. This is done to some degree through academic peer-reviewed papers where teaching pedagogy is written in the form of scholarly articles, hence trying to maximise the time efficiencies one has by fulfilling two obligations – learning and teaching combined with research output. Typically these two activities are done through academic peer-reviewed papers and through the teaching programs where students and staff engage with industry on new product development. However, the nature of these activities means there is often a disconnection between 'academic research' and the development of commercial products. In a sense there is a disconnection between teaching and research. Sometimes this disconnection between teaching and research might be bridged with scholarly contributions or articles in teaching. Design research through practice forms a bridge between the academic community and industry, which can sometimes be distorted through a lack of understanding by both parties, or a lack of willingness to work cohesively together. To link industrial design research to industry, Melles and Kuys (2010) states "the status of industrial design with respect to other professions and disciplines in the industry and manufacturing process remains but has been somewhat modified by the development of an academic research culture" (p. 5228). The work highlighted in both case studies represented in this paper gives greater insight into successful means to link scholarly design research with industry while ensuring research targets are met within a university environment.

'Research' is contextualised by what the government (and therefore universities) recognise as research. For the 2012 Excellence in Research for Australia (ERA) submission, research is defined as "the creation of new knowledge and/or the use of existing knowledge in a new and creative way so as to generate new concepts, methodologies and understandings. This could include synthesis and analysis of previous research to the extent that it is new and creative (ERA 2012 submission guidelines, p. 12). This also includes 'non-traditional research outputs.' These include "original created works" which "must have been made available publicly" (p. 44). This includes design work described as "realised, constructed, fabricated or unrealised building or design projects. Unrealised projects must have an output that provides evidence of the research involved" (p. 46). This paper provides knowledge on research-led practice in design research with case studies showing "realised" research output used to synthesize a new contribution to knowledge through industrial design practice.

# Constructive design research

“Researchers make prototypes, products, and models to codify their own understanding of a particular situation and to provide a concrete framing of the problem and a description of a proposed, preferred state… Designers focus on the creation of artefacts through a process of disciplined imagination, because artefacts they make both reveal and become embodiments of possible futures… Design researchers can explore new materials and actively participate in intentionally constructing the future, in the form of disciplined imagination, instead of limiting their research to an analysis of the present and the past” (Zimmerman & Forlizzi, 2008, as cited in Koskinen, et al., 2011, p. 5).

These definitions identified by Koskinen, et. al. (2011) presents a distinct contrast between researchers, designers and design researchers. The term “constructive design research” is used by Koskinen et al. (2011, p. 5) as a new name to “research through design” because it creates a new beginning, clarifies older names given to design practice as research and promotes construction as an essential tool used in this kind of research. The definition given to constructive design research “refers to design research in which construction — be it product, system, space, or media — takes centre place and becomes the key means in constructing knowledge” (Koskinen, et al., 2011, p. 5). Therefore, products that push the boundaries of new materials or manufacturing techniques are often dissected and disassembled to purposely create new knowledge.

“One of the deep problems in design research is the failure to engage in grounded theory, developing theory out of practice. Instead, many designers confuse practice with research. Rather than developing theory from practice through articulation and inductive inquiry, some designers mistakenly argue that practice is research” (Friedman 2008, p. 154).

Friedman’s claim indeed identifies a common misunderstanding between industry practice and research-led practice in academia. Friedman’s (2008) argument continues by introducing tacit knowledge and highlighting another misconception that “the notion that tacit knowledge and design knowledge are identical as sources of theory development is linked with the idea that practice is a research method” (p. 155). In keeping with Friedman’s perspective, tacit and design knowledge are separate entities. Tacit knowledge is knowledge known by practitioners from experience. Design knowledge however, is knowledge attained from experimenting and practicing design. This claim is further clarified when Friedman (2008) notes “the fact that reflective practice itself rests on explicit knowledge rather than on tacit knowledge” (p. 155). Again in this context, practice is used to investigate and discover explicit knowledge as opposed to tacit knowledge known by professionals. “While we learn the art and craft of research by practicing research, we do not undertake research simply by practicing the art or craft to which the research field is linked” (Friedman, 2008, p. 156). This claim is imperative to understanding that a designer cannot practice design and therefore, claim this practice is research. However, unless the design practice is substantiated in a way that is recognised as scholarly research by defining what the design questions and intent are, and the result is a contribution to new knowledge, the act of design practice is simply design practice not design research.

By identifying Friedman’s (2008) concern about design researchers failing to engage with grounded theory, the case studies used in this study adhere to Frayling’s (1993) theoretical design research model of research “into”, “through” and “for” design (p. 8). Research into design is an exploration of existing knowledge from literature and historical evidence of design solutions. Research through design is the act of design practice to explore design constraints and considerations towards designing new innovative products

and applications and research for design is the development of a design artefact that is a refinement of initial design concepts generated through design that embeds a new contribution to knowledge.

The development of an artefact is an important element to industrial design research-led practice. Further criticism is given to this research contribution as it is commonly argued that the researcher receives credit for the artefact in substitution for the theory produced. Biggs (2002) however, refers to artefacts as embodied knowledge (p. 5) of what has been found through research and further states "neither artefacts alone nor words/texts alone would be sufficient" (p. 6). In respect to making claim that the artefact is a substitute for written text, it must be noted that researched literature has emphasised and informed the development of a design artefact. The design process is another contribution to new knowledge as it depicts the process of practice and presents it in an accredited academic representation (Biggs, 2002, p. 2).

## *Case Studies*

In order to qualify this study Frayling's (1993) design research theory is used to disseminate the following case studies conducted through research-led practice for design research. The two case studies shown conform to similar industry-linked activities with vastly different outcomes. It is the authors' anticipation that these case studies provide an insight into how industrial design practice from an academic context can better work with industry to look deeper into research issues that a design consultancy does not have the time or money to pursue in research and development. It is important to note that the research completed within the context of the university environment is not to compete with product development companies. Research within the university looks at 'design knowledge' with the purpose of problem finding, rather than problem solving. This creates a level of curiosity with a direct purpose to identify new design opportunities, which companies can certainly do, but may not have the time or resources to dedicate. It must also be noted that while design research-led practice in academia has the intention to contribute a new body of knowledge to society, design practice in industry is conducted to generate contemporary and future product design solutions for consumer markets.

The case studies presented in this study were conducted for industry in an academic context. The purpose of presenting these case studies is to highlight the use of grounded theory to generate a new body of knowledge through industrial design research-led practice in academia for industry.

## *Case Study 1: Blair Kuys*

### New product design and commercialisation

This case study highlights methods of engagement between researchers within academia and industry, showing the level of detail required to advance a project past the conceptual stage and emphasises the design process undertaken for this project. This is done to communicate how a traditional industrial design activity of this nature can disseminate research-led practice that is recognised by the university and government as research. This industry linked research-led practice was initiated by the observation of a Small to Medium Enterprise (SME) that invested heavily in capital equipment that was currently underutilised. This observation led to a search on how research-led practice could link with traditional theoretical research that would be recognised by the university. From this,

Enterprise Connect[1] was cited as the potential avenue to pursuing this venture. Enterprise Connect provided the company with funding for 50 per cent of salary costs (to a maximum of $AUD50,000) for a one-year placement.

The aim is to:

- Help break down the cultural divide between business and the research sector,
- Speed up the distribution of knowledge and expertise, and
- Accelerate the adoption of new ideas and technologies.

After this contract was organised between both parties work commenced to create new products for the company involved, which enabled this company to substantially expand the range of products currently produced. These new products complimented the manufacturing capabilities that already existed and improved their capacity utilisation.

From this, a connection was made to the buying group for one of Australia's largest hardware companies and concepts were presented to gauge interest. This was positively received and gave a better understanding of price sensitivities, new product needs and their customer's aspirations. This references a design method showing the importance of high-quality visuals in presenting ideas to a client by providing greater importance in the front-end of design activity to help 'sell' an idea (Kuys, Thong & Melles, 2010).

This formed the next phase moving from initial concepts to product refinement, prototyping and ultimately production. Without understanding the interest levels from the buying group for these particular products, the project would not advance, as there is no point investing heavily in new product developments that don't have a market.

In a study from Gemser and Leenders (2001), it was found that the extent to which firms integrate industrial design in new product development projects has a significant and positive influence on company performance, in particular when the strategy of investing in industrial design is relatively new for the industry involved. This was the premise behind this entire project, as the manufacturing company involved had never engaged with industrial design before. Results of this particular case study reconfirm the positive influence industrial design can contribute to company performance.

The first stage of the design process for this case study was initiated by research into design as highlighted in Frayling's (1993) design research model. The primary method used in this case study was market analysis. The initial primary target market was identified as the DIY homeowner. This was determined, as an identified gap was established for affordable quality products with an emphasis on aesthetics and functionality for the domestic garden. Current products on the market are commonly cheap imports or high-end products that lack DIY qualities. The market segment in which this case study was positioned is the Australian hardware market, identified as having considerable growth over the last decade and is now generally accepted to include home improvement, home leisure and building products. The market is currently estimated to generate sales of approximately $AUD19 billion per annum (Australian Bureau of Statistics, 2013).

[1] Enterprise Connect is an Australian Government initiative in the Department of Industry, Innovation, Science, Research and Tertiary Education that offers comprehensive advice and support to eligible Australian small and medium-sized enterprises to help them transform and reach their full potential.

## Market analysis (research into design)

This initial research led to the identification of three product categories that fit within the manufacturing capabilities of the company involved. These three categories are represented as follows:

**Creeping plant panels** – Existing products in this category have minimal design input and lack DIY qualities as seen in Figure 1.


Figure 1. Examples of current products used for creeping plants.

**Privacy panels** – Existing products in this category have minimal design and made from cheap materials with a poor service life as seen in Figure 2.

Figure 2. Examples of current products used for privacy screens.

**Feature light panels** – Existing products in this category have good design resolution but lack DIY elements and are usually very expensive. A majority of these products are sold as ‘one-offs’ and in most parts specified by architects or landscape designers. Examples are seen in Figure 3.

Figure 3. Examples of current products used for feature lighting.

Figures 1 to 3 are examples of research into design to identify existing product designs and historical evidence of design solutions. After the product categories were defined, this project followed the process of typical product development (research through design), while at all stages of conceptual design, the target market and manufacturing capabilities were considered. As defined by Ulrich and Eppinger (2008) a process is a sequence of steps that transforms a set of inputs into a set of outputs. It must be noted however — like many product development previously — the progression of this complex sequence of steps is not linear, as areas within the product development process cross-lapped and were resolved in a circular fashion. However, the following shows the evolution of this project (presented visually) from initial concept development as research through design to the final production and retail of the product (research for design). All of these stages are identified by many (Roozenburg et. al., 1995, Dorst et. al., 2001, Gemser et. al., 2001 and Ulrich et. al., 2008), as key stages in the successful development of a commercial product. The following visual evolution of this case study also follows the four stages of the design process as highlighted by Ho et. al. (1997) earlier in this paper.

## Concept development (research through design)

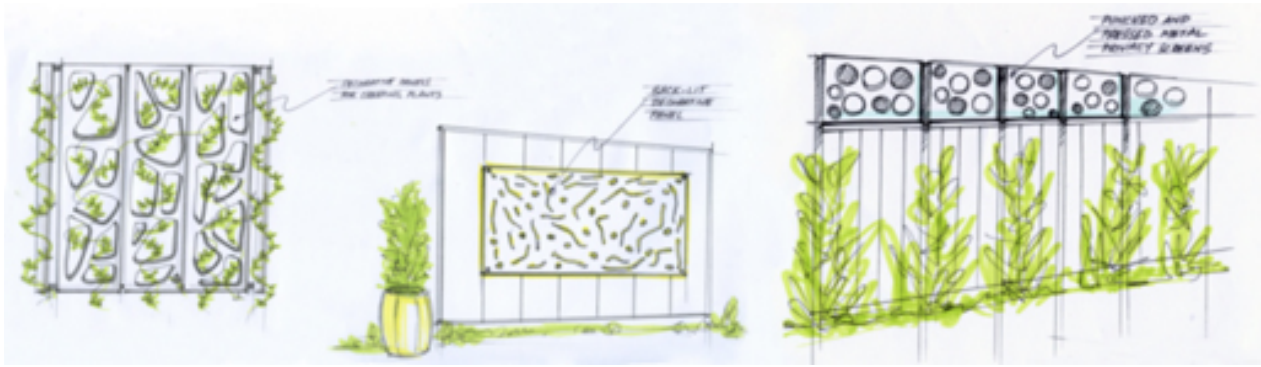

Figure 4. Examples of initial sketching used to advance the design outcome.

## Concept proposal/selection

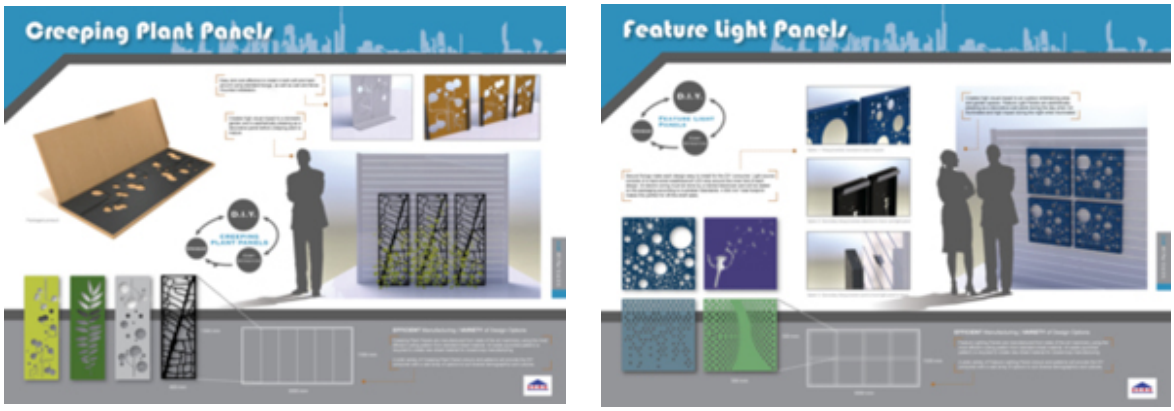


Figure 5. Examples of presentation panels used to communicate the product concepts.

## Concept refinement/detail design

Figure 6. Refinement using 3D CAD software and hand sketching helped better link the product to the intended market and to the manufacturing capabilities.

## Finite Element Analysis (FEA)


Figure 7. FEA used to simulate different forces applied to the product. This is a valuable stage in the design process to further refine the product outcome before investing in production.

## *Prototyping (research for design)*

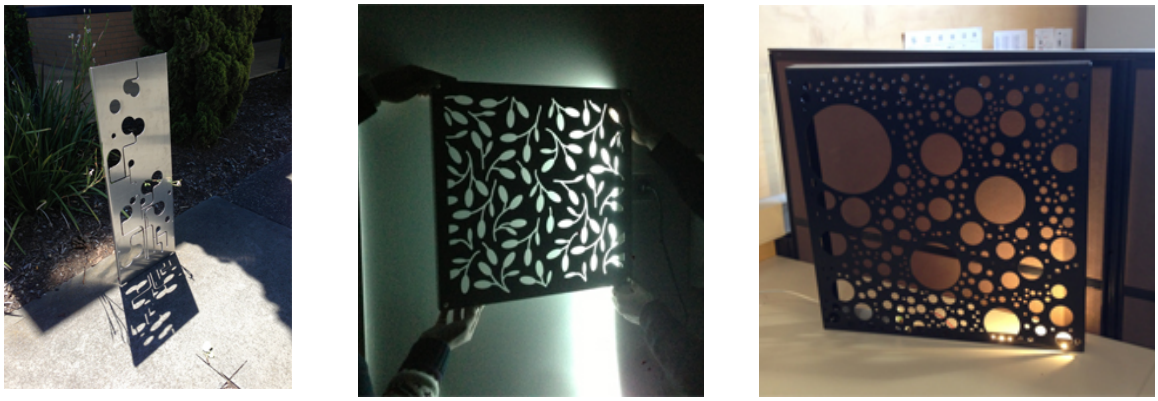

Figure 8. Prototyping was completed on various designs using different materials and thicknesses to find the optimum product outcome. It must be noted that prototyping occurred on five separate occasions — all with minor iterations — until final manufacturing took place. In respect to Frayling's (1993) design research model this stage of the theoretical model demonstrates the research into and through design as a design artefact. The knowledge attained from the design process is embedded into a final artefact where audiences can view the product outcome and understand the design research conducted to produce the final design solution.

## Testing in context

Figure 9. An example of prototyped products in context. This was used to better understand to issues associated with DIY installation and longevity of products in its intended environment.

## Manufacturing


Figure 10. The final products being manufactured.

## Retail/marketing


Figure 11. Virtual rendering of packaged product.

Figure 12. Virtual rendering of Creeping Plant Panels.

Figure 13. Virtual rendering of Privacy Panels.

Figure 14. Virtual rendering of Feature Light Panels.

This project followed various design methods to successfully achieve the projects intentions – that is to diversify the product range by this particular manufacturer by using the existing capital equipment in place. From an industrial design perspective, this is a useful example of linking research-led practice with industry to create commercially viable outcomes. The estimated value this project brings to the manufacturing company involved is $AUD1.3 million based on 15,000 products selling of each design per year. This in turn is estimated at creating profit revenue to the retailer of $AUD2.1 million in the first year of sales.

The success of this case study can be summarised by Hertenstein et. al. (2005) who states; “Industrial design is one of the several key areas critical to new product development, together with research and development, marketing, manufacturing and purchasing, among others… Researchers in fields like marketing such as Dahl et al. (1999) and Srinivasan et al. (1997) have acknowledged the importance of the role that Industrial Designers play in producing products that are successful in the marketplace” (Hertenstein et al., 2005, p. 4).

## *Case Study 2: Christine Thong*

### Changing behaviour through design: door handle design

This project also supports the validity of research-led practice to be a scholarly activity that contributes a new body of knowledge to society that can lead to benefits for industries in the private sector. Metro Trains Pty Ltd, is a private company servicing Melbourne’s

public train system. They have engaged with Swinburne University of Technology to conduct industrial design research as an Australian National Competitive Grant, Category 3: Industry research income.

The purpose of this project was to conduct user-analysis research to inform the re-design of handles featured on the *Comeng* style train saloons. Even though the current handle design works extremely well, the very fact it allows the general public to easily grip the handles in many different ways to gain leverage to open the doors is what enables the general public to pry the doors open when they should not. This is a common occurrence, with many successful attempts leading to serious injuries and in one circumstance, death.
The bulbous shape of the protruding door handle was designed to allow for those with reduced wrist and hand strength to grip onto the doors, but the protrusion also allows for bags and clothing to become entangled in a way that people can be dragged along by the train. Driver vision of people trying to open train doors from the outside as trains are taking off can also be impaired with the shape of train lines curving slightly as they depart from the station, therefore it can easily go unnoticed if someone is caught on a door handle.
One solution considered by Metro Trains was to introduce a sensor system that would alert the driver if the doors were not closed properly, however this system is already in place and ineffective because of the placement on the drivers 'dash' board. The red light indicator hidden from sight when in the driving position and the noise indicator ineffective with train acoustics. To re-design the system and install this in *Comeng* style trains would cost a few million Australian dollars to implement, which was not deemed economically viable given these trains were scheduled to be retired in five years time. It also would not do anything about altering the behaviour of people trying to open doors when the train is departing from the platform.

Another solution to the issue considered was to change the door system to be automated push button entry, however this would again cost a few million Australian dollars to implement and not provide economic viability.

Therefore Metro Trains determined that the project was required to deliver a low-tech, cost effective solution that could minimise dangers and unsafe behaviours of people trying to open train doors when they should not. Given the parameters identified by Metro (research into design – history proves that there are safety issues with the current handle design), research through design explores if the re-design of static door handles based on user-analysis research can deliver a low cost solution that increases safety and minimises the ability of people to engage in dangerous behaviour. The design challenge is finding a balance of a door that is extremely difficult to open while under pressure to stay closed (when the train is moving) but easy to open when the doors are not under pressure (when the train is stationary at the platform). The scope of the current project was to take the concept to proof of concept prototyping stage, where-by the prototype could be used for user-testing, and it was identified that all methods for opening doors could not be mitigated through the project. For example, if a person manages to catch the doorframe while it was still open, a different handle would not affect this behaviour.

User-analysis research was conducted using a range of non-invasive techniques, preferred by Metro Trains, to triangulate findings. The methods were:

- Observing people embarking and disembarking from *Comeng* trains on three different platforms during peak and non-peak periods over two-weeks, using Metro Trains video footage,
- Informal interviews with relevant Metro Trains staff,
- Review of reported incidences for twelve months prior,
- Artefact analysis including measurement of forces required in practice to open doors and experimentation with different techniques for opening the door.

## Identifying the problem (research into design)

User analysis identified that techniques for opening doors when a train is moving and the doors are under pressure to stay closed are extremely varied for both inside and outside of the train. However, there were two techniques that were repeatedly identified:

- Foot push assist for the interior of the train (see Figure 15).
- Full handgrip from the exterior of the train (see Figure 16).

Figure 15. Foot push assist.

Figure 16. Various grips for the handle, including multiple full handgrips, used on both the interior and exterior of trains.

Through the findings of the user-analysis research, the objective of design work was further refined through better understanding the techniques used to open doors. To minimise unsafe behaviours, the design should limit any leverage gained from protrusion necessary in the foot push technique in Figure 15, and the ability to gain full hand grips. This form of research into design identifies design problems with existing door handles.

## Concept development and prototyping (research through design)

A range of solutions were ideated, considered and developed through prototyping iterations and consultation with the industry partner Metro Trains.

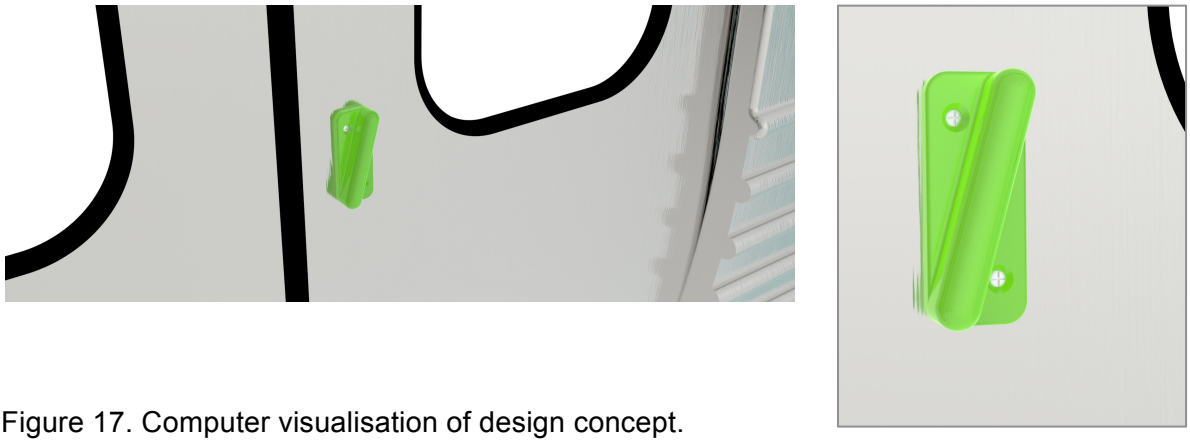

Figure 17. Computer visualisation of design concept.

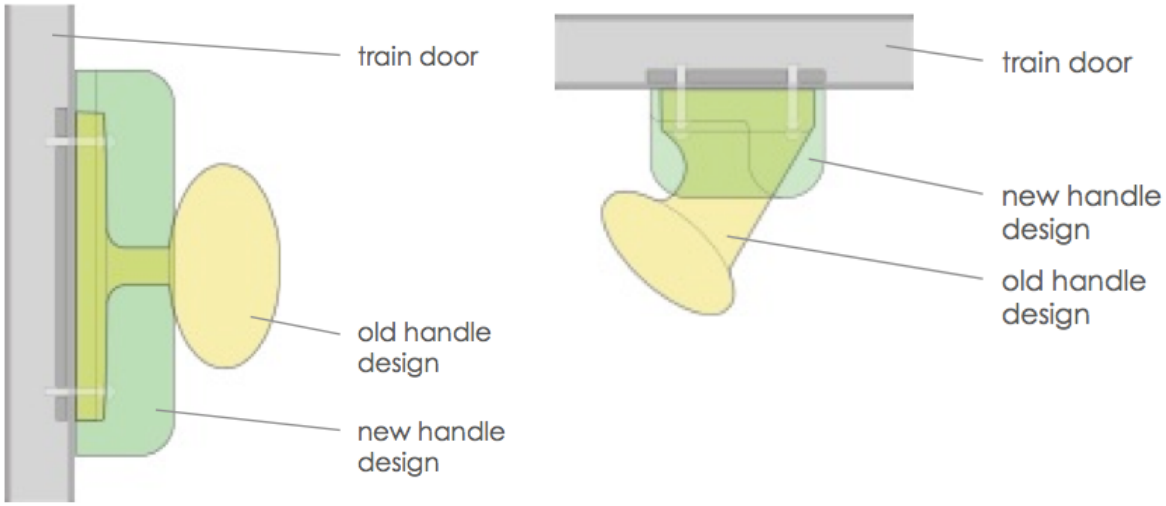


Figure 18. Top and side profiles comparing a door handle design concept to the old *Comeng* door handle design.

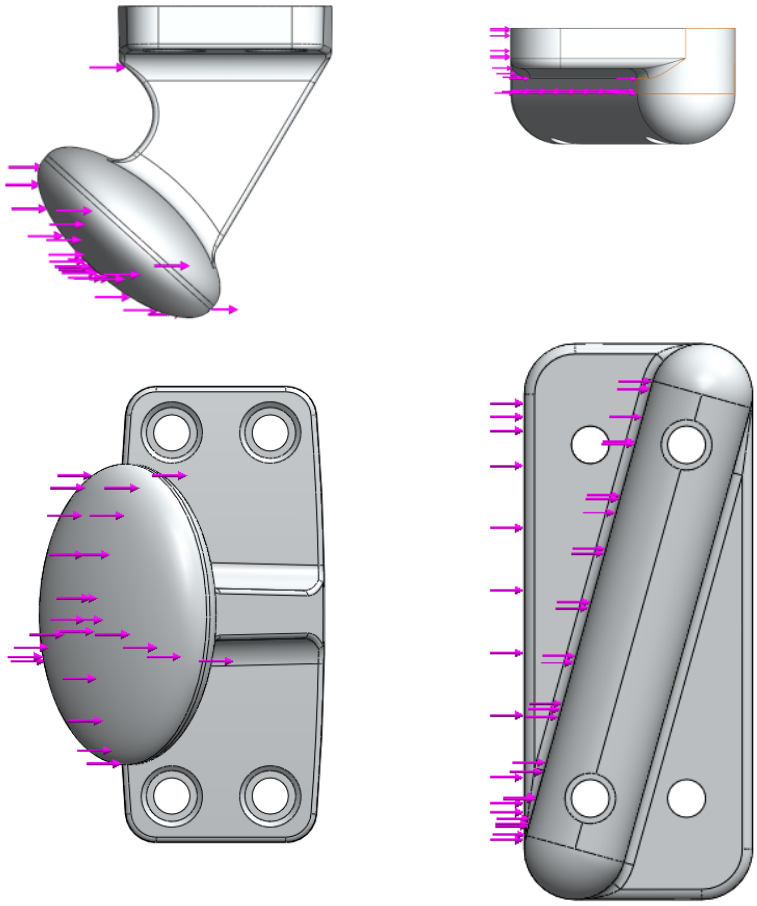

Figure 19. Predictive modelling to simulate forces of 500N, repeatedly applied to simulate use of the door handle over a period of 10 years, with a safety factor of 1.18 integrated.

## *Design outcome (research for design)*

The key features of this design — identifying how the design has met the project requirements — is summarised as follows:

- Form: lessened protrusion and no sharp edges or details for any clothing or carried items to become entangled (see Figure 18).
- Slide grip: similar to a sliding door, can pull with fingers or push with palm, 12 degree angle to allow for a palm to more comfortably press makes it harder to engage foot assist. Index finger is able to apply 40–60N of force.
- Manufacturing efficiency: same handle design for inside and outside the train saloon, suitable for die-casting required for high volume production.
- Assembly efficiency: same mounting assembly as existing handle, with only two screw points to minimise labour and resources. This was predictively modelled to simulate use over a 10-year period, for which it performed.

The estimated cost of implementing the new door handle design is anticipated to be under $AUD400,000, which is at least one-quarter the cost of other automated solutions. The project to date indicates it will be able to successfully provide an economically viable, low-tech solution required by industry partner Metro Trains to improve the safety of users. The project has delivered proof of concept prototyping (at the time of writing) – the next stage

is to conduct user-testing and mechanical-testing for one last iteration of refinement before production of the door handles and trial installation on *Comeng* train saloons.

The artefact itself synthesizes research, through industrial designs ability to integrate a balance of resource constraints, ideas and user-needs into a form that can be manufactured, produced and ultimately used for the benefit of society. Through application, the knowledge embodied in the artefact is disseminated in the real world.

## *Conclusion*

Often published literature in design research explores theoretical content that has minimal impact on society and real-world application. This study aims to empower industrial design research-led practice in academia, grounded by design research theories by demonstrating how it can be used as a tool to generate a new body of knowledge to benefit industry, while rewarding the university through grant funding and the development of closer relationships with industry partners.

Researchers who "engage in doing design work… directly impact practice while advancing theory that will be of use to others" (Barab & Squire, 2004, p. 8). In the context of this study the design process will impact practice, through which the findings are grounded by theories that can be useful to others. Industrial design research-led practice is beneficial to industry-linked projects by developing appropriate artefacts used to generate a new body of knowledge through scholarly recognised design research. Results developed through practice identify all stages in a design process to inform others on the requirements to best demonstrate design theories in practical outcomes.

Tacit knowledge as an exclusive knowledge known by specific professions (in this context, industrial design) is identified by Rust (2004) as a way that designers who research to inform practice can generate new knowledge and ideas through design artefacts (p. 84). These artefacts are a form of communicating a designer's tacit knowledge as new knowledge to other professions through a range of different ways such as product and user interaction or simply by observation. In addition, other professions can therefore, relate to the artefact and further evaluate and develop the new knowledge as potential future research. In regards to the two case studies presented in this paper, tacit knowledge and design knowledge attained from research and practice will assist in developing an artefact that is appropriate to a research topic, demonstrates the design process, gives credit to scholarly industrial design research-led practice and presents the overall project journey so other professions can understand the new knowledge demonstrated. The designed artefacts in both cases act as an exemplar product where the application and new knowledge gained can be transferred into other products of similar nature.

Although some question the value of practice in design research (Durling 2002, p. 79–85), prototyping — a typical form of design practice — in the design research process has significance for knowledge creation in creative arts and industries (Mäkelä 2007, p. 157–163). In this study, the artefact or project, reflection and practice plays a role as the material resolution of practical "applied" problems with more general theoretical or methodological consequences (Pedgley and Wormald 2007). The issues of knowledge and making in design research have particular relevance to industrial design (Kuys, 2010, p. 61).

The legitimacy of research-led practice in design research as an academic and research intense field cannot be developed alone through theoretical papers in the literature. Rather, research-led practice in design research must prove its value in academia and industry as offered by the two case studies shown. These cases highlight the practicality

of design research which helps bridge the gap between industry and universities. Essentially, this approach must be formally recognised and valued by two different entities with unique cultures – universities and industry. Industry want value-added outcomes, universities want peer-recognised knowledge disseminated through books, papers and conferences. Governments want both but in the main do not have sufficient funding mechanisms or incentives to bring the two together.

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