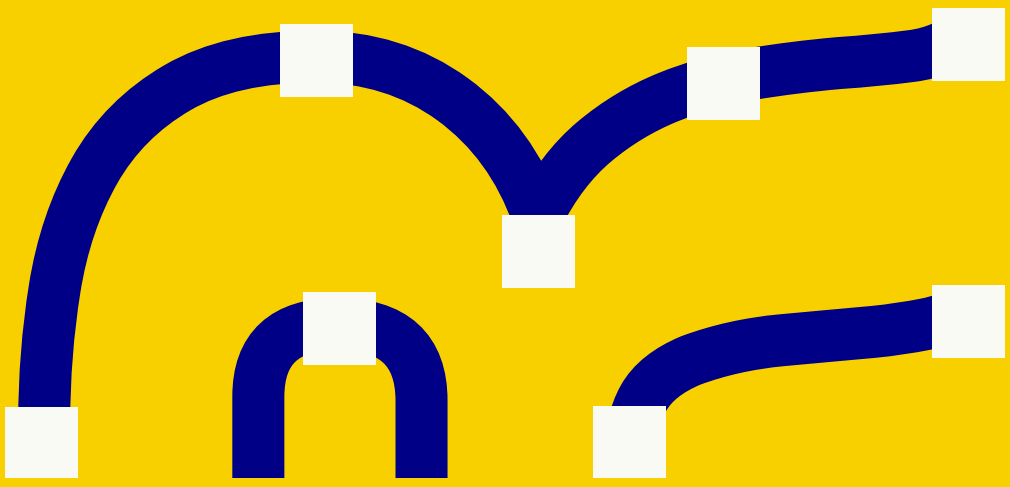
TO GET THERE: DESIGNING TOGETHER

Cumulus Conference Proceedings Paris 2018



Cumulus Conference
Proceedings Series
03/2018 Paris

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Conference Proceedings
Series was developed in
2018 by Jani Pulkka

Cumulus conference
To get there: designing together hosted by CÉSAAP
Conférence des écoles
supérieures d'Arts appliqués
de Paris in Paris, France
on April 11–13, 2018.
Conference website:
www.cumulusparis2018.org

Published by Cumulus
Cumulus International Asso-
ciation of Universities and
Colleges of Art, Design and
Media. Aalto University, School
of Arts, Design and Architecture
PO BOX 31000, FI-00076 Aalto
www.cumulusassociation.org

ISBN 978-2-9565440-0-5 (E-book)
ISSN 2490-046X

Publications in Cumulus Conference Proceedings Series

01/17 Kolding, REDO
02/17 Bengaluru, Letters to the Future
03/18 Paris, To get there: designing together
04/18 Wuxi, Diffused Transition & Design Opportunities

TO GET THERE: DESIGNING TOGETHER

Cumulus Conference Proceedings Paris 2018

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Proceedings Series

Cumulus Association of
universities and Colleges
of Art, Design and Media

Paris 2018

Spaces of Play and Language Games

In a conversation with Fulvia Carnevale and John Kelsey published by *Artforum* in 2007, Jacques Rancière suggested that: "The fundamental question (was) to explore the possibility of maintaining spaces of play". This phrase could summarize the whole Cumulus-Paris project "together/to get there". And all the more so since he added that: "The main enemy of artistic creativity as well as of political creativity is consensus". Living, speaking and working together doesn't mean living, speaking or working within given frames and following given rules, but producing language games and accepting the inherent possibility of misunderstandings. Being together is not thinking, speaking and producing everything alike, and consensus is far from an ideal as soon as we want to create! Quite the contrary, being together means recognizing what divides and opposes us, and being able to overcome differences without foreclosing or erasing them. Therefore we have to speak about discrepancies, we have to show them. In fact, we are at a crossroads and we need to question design and its forms and functions. The Paris Cumulus conference would like to address contemporary issues through conversation and critical spirit. It aims to bring together different

design practices and theories, in order to create an open forum for debate between different points of view and practical confrontations. It should set out to recover positive disparities and pluralities within design practices, beyond classical boundaries. It should even stage moments of dissension in order to explore the possibilities of dialogue and perhaps to demonstrate a new type of porosity or permeability, or even new cultural values. It aims to recognize various forms and various degrees of the discipline in order to forge a space of play where making things together is a priority and where we can engage new social subjectivities.Beyond the questions raised by design itself, being together points to the complex interwining of languages we could share. But emphasizing language certainly does not imply emphasizing semantics or meaning in a postmodern way. Here language is to be approached from the political dimension of being together. Let's hope a conference can be an experimental engagement through conversation which allows us to smoothly shift our attention from everyday life. Let's hope it could have a catalyzing effect on the design community by opening up debate. Being together should allow new connections to be made while asking what we have in common, while pointing out similarities among supposedly polarized practices, but also while recognizing differences and stating that they can co-exist.

Claire Brunet
Head of Design Department –
Lecturer at École Normale Supérieure Paris-Saclay
President of the Scientific Committee

Dear Cumulus Members, Colleagues, Students, Friends,

We were back in Paris, the city of Freedom and Revolution, of Love and Poetry. Cumulus is constantly attracted by Paris.

We came here in 2002 thanks to the Cumulus conference hosted by ESAG with an incredible exhibition at the Carousel du Louvre called European Way(s) of Life (EWOL) as visited by over 23,000 people in two weeks. At that time, Cumulus was just European. In addition, one of the students of our member universities that exhibited in EWOL, he is today, in 16 years, the chief designer officer of Pepsi Co. His name is Mauro Porcini. It seems, based on this experience to be in Paris brings luck and broad perspectives! We came back in 2011 hosted by Strate College, after Cumulus conference in Nantes France in 2006; we were already a global association. We came again to take part in this new 2018 Cumulus conference in France organized by the four schools of Art and Design of the city of Paris, the Ecole Boulle, Duperré, Estienne and Ensaama.

The four Cumulus member universities in Paris, also known as Conférence des écoles supérieures d'Arts appliqués de Paris (CÉSAAP), were created in the late 19th Century to educate the best artisans and creators of textile, fashion, metal works, furniture, graphics, etc. adopting a cross-curricular and interdisciplinary approach; combining design with the intelligence of the hands; fostering innovation as well as increasing and updating the values of tradition and handcraft.

In partnership over the past two years within the framework of CÉSAAP, these four Parisian schools decided to welcome Cumulus back to Paris: To share their expertise, to mutualize experiences and display the results through exhibitions and presentations. Quite a brave decision....and what a challenge!

We all know how challenging but always rewarding, too, it can to organize a Cumulus conference as a single institution; we can just imagine the complexity in sharing duties and responsibilities for this demanding task among the four different institutions spread in four different locations in the city of Paris. Thank you to all the heroes and their staff for making it possible: Annie Toulzat, Josiane Giammarinaro, Annie-Claude Ruescas, Laurent Scordino-Mazanec, Etienne Périn, Claire Pinault, Claire Brunet, Laurent Bailly, Anne Barrois, Isabelle Basquin, Caroline Bougourd, Bernard Bréchet, Lucinda Caton, Lyne Cohen-Solal, Gilles Deléris, Jacques-Antoine Drouard, Éric Dubois, Mariette Dupont, Lauriane Duriez, Damien Ehrhardt, Brigitte Flamand, Marie Jonquet, Élisabeth Lafay, Natacha Lallemand, Héloïse Leboucher, Raphaël Lefeuvre, Céline Mallet, Clémence Mergy, Luce Mondor, Yves-Marie Pinel, Rémi Roudeau, Jean-Louis Soubret, Emmanuël Souchier, Apolline Torregrosa, Jean-Christophe Valleran, and all the members of staff of all four schools. This conference was a super positive and a very advanced Cumulus case study.

The title of the conference was summarizing this shared spirit and approach: TOGETHER.

The term Together deeply condenses the fundamental principle of our beloved Cumulus Association to: Do things together; design together; imagine, learn, think, seek, innovate, create, make and build together; To educate and to research together – leaving behind all that divides, opposes and excludes; creating solid and beautiful bridges between different competences, visions and perspectives, cultures and traditions. We met in Paris in April 2018 TOGETHER,

and Cumulus platform being essential to that, to create spaces and times, where and when; to help us all in a collective manner to share perspectives and expertise; to remind us values and meanings.

As in the past conferences, I liked to stress the fact that, I was there on stage alone but not serving the association alone but TOGETHER with wonderful colleagues. Starting from the Cumulus Vice Presidents Elsebeth Gerner Nielsen Denmark and Sam Bucolo Australia that unfortunately couldn't be here with us, and Cumulus Executive Board members José Allard Chile, Mariana Amatullo US, Robin Turner South Africa, Lorenzo Imbesi Italy, Ulrich Schendzielorz Germany, Xiao Yong China, Sara Hyltén-Cavallius Sweden and Rachel Troye Norway: Concluding the list with our essence of Cumulus: General Secretary Eija Salmi and Cumulus coordinator Justyna Molik both from Finland. Thanks to all their support I was able to welcome all conference delegates and contributors to these inspiring days.

TOGETHER finally means to me also to be open to the new, to the ones that are not part of our community yet: New members, new colleagues, new students, new partners.

During these days, we were welcomed new special guests:

The two Cumulus Student Ambassadors nominated by the last 2017 Conference organizer: Ms Saili Palyekar and Mr Nitish Chopra of the Srishti Institute of Art, Design and Technology, Bangalore, India. And the three representatives of Cumulus Plus+ program and coming from Brazil, Macedonia, Tunisia, who brought new horizons for Cumulus by joining this Paris conference: Mrs Polise de Marchi, architect and designer, SENAC University Center, Brazil; Mrs Gordana Verncoska, vice dean of Faculty of Art and Design, European University, Macedonia, Mr Dhafer Ben Khalifa, lecturer at the Higher Institute of Fashion Design Monastir, Tunis, Tunisia.

This conference also opened the door to 25 new Cumulus full and three associate members.

We really invite you to discover these new realities and to start including them deep in our Cumulus Family.

All TOGETHER.

Luisa Collina
Cumulus President

Call for papers and selection procedure

We are very pleased to present the online Paris To Get There – Paris Cumulus Conference Proceedings 2018. The conference call received a great international response with over 180 submissions from more than 50 countries. 62 papers, 2 films and 1 poster were selected from a total of 188 proposals, and all contributions were double-blind peer-reviewed by the international review panel of 80 members. These papers and films were accepted for our Parallel Sessions including oral presentations.

We offered our contributors the possibility of submitting academic or professional proposals (32 academic papers – 33 professional proposals including films and a poster). We would like to take this opportunity to thank all the presenters for submitting their work and attending the conference at École Boulle, École Duperré, École Estienne and Ensaama in April 2018. The Cumulus Conference 2018 in Paris adopted a cross-curricular interdisciplinary approach which highlighted collective and collaborative interest. Thanks to your contribution and the participation of almost 350 delegates during the 3 days of the Conference, we contributed together to make otherness a positive force, and to ensure that design and this union of talents become an undeniable tool for action on reality.

Thank you!

Césaap
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I. Language

II. Innovation

III. Conflicts

IV. Actors

V. Alone

Research Prototyping, University-Industry Collaboration and the Value of Annotated Portfolios

Roderick Walden, Stefan Lie, Berto Pandolfo, Anton Nemme

Abstract

The purpose of this paper is to describe how a team of academic-design practitioners working on a university-industry collaboration (UIC) project, used the method of *research prototyping* documented in an *annotated portfolio*, as a way to meet the dual need of contributing to the academic discussion and, problem solving through design practice. The annotated portfolio enables knowledge transfer and knowledge sharing, integration of new knowledge through research prototypes and a way of retaining knowledge for possible application in the current or future projects. During the process of conducting the UIC project, a team of three academic design practitioners working in product design research recorded images of prototypes constructed and catalogued those images to be systematically transferred to the annotated portfolio document. The entire body of work was catalogued for analysis (both during and after key project stages) to integrate knowledge generated through research prototypes. This paper will focus on the role of research prototypes constructed as part of the project, the classification of those prototypes recorded in photographs and the function of their arrangement in an annotated portfolio. Academic design practitioners working in collaboration with industry partners do not specialise in particular fields of application, such as furniture designers, medical product designers or in-house product designers. Instead academic design practitioners perform in a similar manner to the consultant designer who is required to quickly master diverse sectors on a continuing basis. The academic team is further distinguished by their focus on research in emergent fields that defy classical categorisation. Due to this, the methodologies through which they build new knowledge in areas of expertise that they're not practiced in, collect this knowledge and portfolio this knowledge is a unique commodity. In the field of design research for UIC projects, more needs to be understood about recording knowledge integration and the role of research prototypes. This research is important because it provides an understanding of how academics may record and contribute new knowledge through UIC projects, where prototype construction is the central research device. Further we propose a method for documenting UIC projects that could be used to help develop the expertise of the academic partner.

Theme: Alone
Keywords: academic-design practice, university-industry collaboration (UIC), annotated portfolios, design research, product design

1. Introduction

The purpose of this paper is to describe how a team of academic-design practitioners working on a university-industry collaboration (UIC) project, used the method of research prototyping documented in an annotated portfolio, as a way to meet the dual need of contributing to the academic discussion and, problem solving through design practice. There are a number of theoretical models that propose ways of managing the combination of design practice and knowledge generation in design research. For example, concerning design *as a part* of research in the generation of theory through prototyping, Stappers (2007) proposes a model that acknowledges the effect of generative and evaluative cycles that direct the development of a central 'product' (which may be a physical prototype). And that this relationship is informed by diverse disciplinary knowledge gathered at the formation of the process as well as by new knowledge brought in as a consequence of the process in order to return insights into those disciplines. UIC projects may be described in a similar way, in that there is knowledge brought in at the start of the project both by the academic team and the industry partner. There is a central 'product' and there is a process that develops symbiotically as knowledge is transferred, integrated, applied and developed. UIC projects must return value to the academic discourse and, we believe, in doing so can represent a unique opportunity for industry. It is important that if UIC projects, as a form of practitioner activity, are to managed as academic research projects that they be knowledge directed, systematically conducted, unambiguously expressed, make methods transparent and make knowledge outcomes that are transmissible (see Archer, 1995). The paper describes a project by the IPD-R Research Unit at the University of Technology Sydney in the Product Design Program that has set an academic focus that frames knowledge directives, as described below:

> The IPD-R Research Unit was established to support local small-to-medium manufacturing business (SMEs) develop innovation strategies connected with new product development. The research unit

comprises of a team of academic practitioners conducting research in product design and manufacture. And the directives of the unit are aligned with the individual specialisms of the team members that combine through collaborative research activities conducted by the unit including for UIC product design projects. Broadly, the IPD-R Research Unit is concerned with strengthening a base for local product design and product innovation for Australian industry and addressing the technical constraints associated with the decentralisation of product manufacturing. The unit operates with a focus on local SME (and micro) business specifically concerned with the production of physical products. The particular specialisms that are used to activate these broader objectives and in-turn nurture the connections between our practice and ability to make contributions to knowledge are:

1. Decentralised manufacturing
2. Micro-business / making
3. Physical interaction with 3D products
4. End-use part production from 3D Printed (AM) polymers
5. Creation of knowledge and intellectual agency through product design practice

Using an example UIC project conducted by the IPD-R Research Unit, the paper provides an understanding of how academics may record and contribute new knowledge through UIC projects, where prototype construction is the central research device. Further we propose a method for documenting UIC projects – a form of annotated portfolio – that could be used to help build a cohesive UIC practice, and develop the expertise and agency of the academic partner.

2. Literature

The connection between research prototyping and university-industry collaboration (UIC) in product design research is one that requires closer investigation in order to further develop into a more stable academic design practice. A number of barriers to successful UIC have been identified including those related to differences in the orientations of industry and universities (Bruneel, D'Este & Salter, 2010). The growth of universities has been dependant on the creation of reliable and public knowledge

(Merton, 1973) and academics typically wish to create knowledge and ideas that will be acknowledged by their peers (Brown and Duguid, 2000). Conventionally, industry creates 'private' knowledge and seeks to appropriate its economic value for competitive advantage (Teece, 1986). In this context, industry conducts research perceived as being valuable for new product or service development for their customers (Nelson, 2004).

2.1 UIC and Research Prototypes

Looking more closely at product design methodology, prototyping is an important research technique in both academic and industry practice and has been described as a central intersection between design research and design practice (Weensveen & Matthews, 2014). Further, as part of a structured exploratory process, prototyping is the only way to understand touch, materials, shapes and interactive features and represent a stable way of inviting collaboration at even the formative stages of the design process where hunches and small discoveries are tested (Koskinen et al. 2011). As such, prototyping may represent a way for UIC product design projects to overcome some of the aforementioned barriers, as its recognised as a valuable research technique in both academic and industry research and it provides a means of collaboration throughout the project. However, the function of prototypes in academic research and industrial research are constructed for different reasons. A recent paper by Koskinen & Frens (2017) distinguishes *research prototypes* as 'theoretical objects' created to test concepts that respond to theoretical literature, from *industrial prototypes* that are created to test issues related to commercialisation such as manufacturability and marketability. Observing and being upfront about these differences is important. Inter-organisational trust has been identified as an issue for UIC and that building a trust-based relationship will improve the capacity of universities and firms to work together to resolve problems and lower orientation-related and transaction-related barriers (Bruneel et al. 2010). Is there a way to manage prototyping activity in UIC projects so that the objectives of both partners can be met? As Archer (1995) pointed out, practitioner activity in academic research must be knowledge directed, systematically conducted, unambiguously expressed where data and methods are transparent and knowledge outcomes are transmissible. The concern then, is for knowledge management through practice. UIC product design projects may represent, what Cowan & Jonard (2009) term a joint innovation alli-

ance where partners combine 'knowledge stocks' to create new knowledge. They determine that the success of such a process is dependent on how well the alliance can secure knowledge complementarity (2009). Given its role in the successful conduct of both academic product design research and industry practice, prototyping that attempts to combine 'knowledge stocks' may be a means to control the development of knowledge complementarity and new knowledge development. And that knowledge may be developed such that its actionable in different ways. Frens (2007) notes:

> "Knowledge on two levels can be gathered when researching product design. We can research aspects of the products themselves, such as form or interface, but we can also research the process of how these products are generated. Products are designed to explore the implications of theory in context. The resulting products are subjected to experimentation in real life situations to understand the complex relationships of humans and designed reality. The assumption underlying the research-through-design approach is that knowledge gained from these products, through experimentation, can be generalised in the form of design specifications for future products and in new theory or frameworks" (Research through design: A camera case study, Frens, 2007).

The academic team needs to manage this process. It has been suggested that for achieving innovation outcomes in interorganisational collaboration portfolios that capture different though complimentary arrangements, can play a supportive role (Faems et al., 2005). Formalising the process of UIC projects, by the academic team is also noted as important for internal value creation. We may consider the academic research unit working in a UIC project as an innovation intermediary that enables their partners to leverage external technologies and knowledge. And it has been found that for innovation intermediaries to perform these tasks successfully they must generate internal value for themselves (De Silva et al. 2016). The research strongly suggests that the success of continued UIC is dependent on the ability of the university research unit to define their internal value and by extension their knowledge-based practices (2016).

The Academic Design model presented by Dorst (2013) argues the need for new models of practice to enable connections between the 'aca-

demic discussion' and 'design' to produce concurrent innovation and knowledge outcomes. And C-K Theory (Hatchuel & Weil, 2003 cited in Hatchuel et al. 2016) proposes a general framework of concurrent concept (C) and knowledge (K) useful in joint innovation projects and particularly for the improvement of existing methods or development of new methods of practice. C-K Theory also requires 'portfolios' to be kept so that connections between concepts and knowledge can be developed in an industrial context and as such may provide a useful point of reference for constructing annotated portfolios in UIC projects.

A few years ago, Bill Gaver and John Bowers (2012) offered the concept of the *annotated portfolio* as a means for explicating design thinking that retains an intimate indexical connection with artifacts (prototypes)" while also addressing broader research concerns (2012). Annotated portfolios may represent a method for formalising UIC project collaboration, building up the internal value of the academic research unit and overcoming orientation-related barriers using prototyping as the central research device for knowledge coordination and generation.

3. The UIC Project

The IPD-R research unit at UTS was approached by an Australian SME (the industry partner) that specialises in plant propagation and supplies young plants to nurseries and growers. The industry partner was seeking a UIC so it could work with a research unit that would be capable of bringing a concept developed by the industry partner to a level at which it could be physically tested and its feasibility assessed. The project was to optimise a specific process of plant propagation through means of detaching the process from dependence on geographical location and labour which would enable production to be more flexible and cost effective.

The project ran for a period of 10 months, from March 2017 to December 2017. During that period six face to face meetings between the IPD-R team and the industry partner were held, three at the university and three at the industry partners facility. IPD-R team consisted of three research academics and two part-time research assistants and the industry partner provided the help and expertise of three of its senior staff and executive whenever it was needed.

Because the project was based on a process, the scope of the project ranged from a review of the established workflow, which uncovered many inefficiencies, to the design and implementation of a new and more effi-

cient workflow. As a result, a completely new process and workflow has been developed, supported by the design and implementation of seven new and innovative tools, all created in collaboration with both parties. The industry partner is currently reviewing the workflow and all tools and assessing them for further development, potential market deployment and using them as a means to secure large scale investment. Due the fact that a new process, workflow and set of tooling had been innovated, intellectual property protection is being investigated for several aspects of the project and therefore no specific details can be disclosed until further notice.

4. Methods

The UIC project was conducted in a dedicated studio space in the Product Design Program at the University of Technology Sydney. The studio has some simple prototyping equipment, a desktop 3D printer, computers with CAD software, bench space for meetings and prototype testing, storage and a small area for photographing prototypes. According to Koskinen (2011) the project adopts a laboratory form of constructive design research where the ability to focus on relationships between various knowledge directives. In this project, one such relationship was between the concerns associated with 3D printed parts for end-use application and physical interaction with 3D products. During the project, certain relationships are more clearly identified as being valuable for more detailed research, made possible by the particular constraints of the design problem set by the industry partner. As such a primary method in the project and the topic of this paper is the production of an annotated portfolio. The portfolio is made up of photographs of all prototypes constructed throughout the project. The photographs are kept in a computer folder accessible by all members of the research unit and at various points in the project, they are brought together into a portfolio format that records their place in sequences of enquiry that contribute both to the creation of product features useful to the industry partner while at the same time contribute to intellectual understandings associated with knowledge in fields of design research that may, for example, feature in scholarly publications in the future. The documentation includes:

1. Photographs of prototypes in sequence.
2. Code and date of prototype construction under each photograph.

3. A table of notes that identify connections between product function and knowledge directed enquiry (knowledge overlaps between practice and theory).

The intention is to ultimately increase the value of the research unit by refining the focus of our UIC engagements such that they build our intellectual agency, enable us to make contributions to the academic discussion and offer actionable design solutions for our industry partners concurrently.

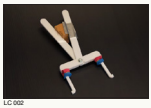
5. Results

Each prototype was photographed after they were constructed. This included rough and quick prototypes that were made as part of an exploratory concept design exercise that may have been to look further into possible future designs, to support the formation of a shared vision or to challenge the team's expertise and build competency in the stated research objectives of the academic unit (see Keinonen, 2006). However, the precise classification and value of certain prototyping tasks was not fully understood at the time of their construction. Creation of the annotated portfolio – itself a reflective design project – helps the academic team better understand the nature of our practice and better define our engagement conditions for valuable UIC projects in the future. The arrangement of photographs in the annotated portfolio were located according to the sequence of their construction and positioned in a horizontal arrangement for design changes that represent a significant evolutionary step forward. And vertical for design changes that represent an incremental evolutionary change. Photographs are coded and referenced in a table that provides more information about the prototype. A sample page has been developed and is presented below (Figure 1).

The prototypes are analysed both from the perspective of meeting the needs of the industry partner and the concerns of the research unit. These are briefly tracked in the table located on each page that lists the prototype code numbers in sequence (Figure 2).

As can be seen in the table (Figure 2) there are knowledge contribution or positioning statements that emanate from the analysis of the prototyping sequence. It's important to note that by constructing the annotated portfolio as a *process* that understandings about certain issues forming part of the academic discussion in design research can be identi-


LC 001


LC 002


LC 003


LC 003.1


LC 003.2


LC 004


LC 005


LC 005.1


LC 005.2


LC 006


LC 006.1

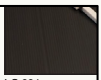
Research Prototyping Sequence
Lifting Clamp System

Prototype	Type	Feature	Material	KCP Code	Knowledge Contribution or Positioning
LC 001	Clamp	Push button action	Timber / metal		
LC 002	Tongs	Handle spring with reverse action	Acrylic	5.LC001-2	Concept design to test knowledge overlaps in the formative stages of UIC projects
LC 003	Tongs	Step action	Acrylic		
LC 003.1			Acrylic		
LC 003.2			Cardboard		
LC 004	Tongs	Centre-hinge spring	Acrylic		
LC 005	Tongs	Geared-hinge spring	Acrylic		
LC 005.1	Tongs	Geared-hinge spring and stabilising coil	Acrylic / PVC		
LC 005.2	Tongs	Geared-hinge spring and stabilising coil / off-set	Acrylic / PVC	2.LC003-5.2	The value of collaborative making in testing material-performance constraints
LC 006	Gripper Unit	Trigger activated gripper unit with geared-hinge spring	Foamcore		
LC 006.1	Gripper Unit	Trigger activated gripper unit with geared-hinge spring and stabilising coil / off-set	Printed ABS	4.LC006-S	Performance factors of springs in 3D printed products for end-use applications

* LC = Lifting Clamp

Figure 1. Sample page from the annotated portfolio


LC 003.2


LC 004

Research Prototyping Sequence
Lifting Clamp System

Prototype	Type	Feature	Material	KCP Code	Knowledge Contribution or Positioning
LC 001	Clamp	Push button action	Timber / metal		
LC 002	Tongs	Handle spring with reverse action	Acrylic	5.LC001-2	Concept design to test knowledge overlaps in the formative stages of UIC projects
LC 003	Tongs	Step action	Acrylic		
LC 003.1			Acrylic		
LC 003.2			Cardboard		
LC 004	Tongs	Centre-hinge spring	Acrylic		
LC 005	Tongs	Geared-hinge spring	Acrylic		
LC 005.1	Tongs	Geared-hinge spring and stabilising coil	Acrylic / PVC		
LC 005.2	Tongs	Geared-hinge spring and stabilising coil / off-set	Acrylic / PVC	2.LC003-5.2	The value of collaborative *making* in testing material-performance constraints
LC 006	Gripper Unit	Trigger activated gripper unit with geared-hinge spring	Foamcore		
LC 006.1	Gripper Unit	Trigger activated gripper unit with geared-hinge spring and stabilising coil / off-set	Printed ABS	4.LC006-S	Performance factors of springs in 3D printed products for end-use applications

* LC = Lifting Clamp

Figure 2. Zoomed-in section of Construction Table

fied between (or across a series of) prototypes. Essentially the research team attempts to clearly articulate the reason for moving from one way of seeing the problem (embodied in one prototype) to another way of seeing the problem (embodied in the next prototype). There are three examples indicated in the sample shown:

►5.LC001-2:
Concept design to test knowledge overlaps in the formative stages of UIC projects.

The use of '5' at the start of the code above refers to the knowledge directive, "Creation of knowledge and intellectual agency through product design practice" from the list of our research teams set of stated specialisms. LC001-2 indicates the sequence across which an interesting event took place worthy of investigation as part of that (5) research area. In this case, the particular nature of this event relates to the way that the working principle of prototype LC 001 is essentially discontinued in favour of the significantly different 'tongs' design represented in LC 002. Though not shown in this paper, there are examples in the annotated portfolio where this 'leap' in direction has occurred in the same project but with different parts of the design in the formative stages of the project. There may be something to these examples of significant design evolution that contribute to the research on determining knowledge overlaps in joint innovation projects (see Cowan & Jonard, 2009). It may also draw in new knowledge about addressing design fixation in the early phases of UIC projects and acting on "prestructures" (proposed by Hillier et al., 1972) which are solution-types deployed to solve problems in new ways by drawing on a "repertoire of design tactics" or "schemata" when limited empirical information is at the designer's disposal (see Parsons, 2016).

►2.LC003-5.2
The value of collaborative making in testing material performance constraints.

The complexities associated with orienting partner incentives in UIC projects may ease with the changing commercial environment for both entities. Leading companies are moving from the traditional R&D model to a D&R (design-led) model where design directs research and technological investment (Koskinen & Dorst, 2015). And today universities are much more entrepreneurial with the aim to contribute to national eco-

nomic development by conducting research that has commercial and industrial application (Etzkowitz et al., 2000; Martin, 2003 cited in Huang & Chen, 2016). These changes are further encouraged by government support policies such as the Australian Industry Innovation and Competitive Agenda (2014) that specifically identifies the formation of innovation strategies related to new product development and advanced production for small to medium enterprise (SMEs) as key. However, UIC product design projects with Australian SMEs often require the careful management of two competing constraints: increasing performance factors while at the same time reducing production complexity. We have found through this project that detailed collaboration with the industry partner that is largely supported by making quick (functioning) prototypes in available materials helped to balance these competing constraints. Research prototypes LC003-5.2 progressed through a making phase that might be described as a 'practice-oriented journey' (Mäkelä, 2007) framed by a series of (roughed out) research questions including how to reduce product complexity for rich interaction (a term used by Frens, 2007), yet open enough to allow rapid exploration reliant on the teams 'know-how' and collaboration with the industry partner.

▶ 4.LC006-S

Performance factors of springs in 3D printed products for end-use application.

The use of 'S' at the end of this code indicates that we are referring to a 'series' of prototyped investigations that would be detailed on a separate page. *The large number of prototypes made progress via lines of enquiry. The process is not linear and there are multiple lines of enquiry that, at times operate concurrently. As such, documenting the prototypes on pages requires a kind of tiered system of organizing information, something like the way a set of engineering drawings have top level (GA), sub-level (sub-assemblies) and base level (part drawings) to organize the detail.* The 'S' refers to a 'series', and in this case, after the concept for interaction was approved, the LC006 series involved a deep investigation of how to achieve high-level performance requirements using 3D printed parts for end-use application. At the time of writing this paper, confidentiality agreements prevent us from showing more detailed prototypes. However, there was a side investigation to test the performance of integrated 3D printed springs over bought-in mechanical coil springs to be located within the unit. The investigation proceeded via the construction of vari-

ous 3D printed springs to be printed as part of the internal geometry of the housing. These were trialed in different materials using different methods. Significantly, these have not been adopted in the current design, but they represent valuable materials research for the development of the expertise of the academic team. And therefore, form part of the annotated portfolio of this project.

6. Conclusion

The study demonstrates that the use of annotated portfolios is beneficial in the conduct of university-industry collaboration (UIC) product design projects, particularly for orienting the purpose of research and industry prototypes. The research builds upon the definition of annotated portfolios presented by Gaver and Bowers (2012) that described the annotated portfolio as a document containing annotated images of prototypes as a means of explicating design thinking and links to theory. UIC partnerships ought to strive for innovation so that the outcomes can benefit both the industry partner by way of providing new products or processes, and the academic partner in the form of contributions to knowledge that can be disseminated through publication. The annotated portfolios described by Gaver & Bowers are limited in the UIC context because the prototypes developed by their studio are predominantly linked to theory and serve as "conversation pieces or curiosities" to contribute to design research (2012). These types of prototypes have been described as research prototypes – theoretical objects subjected to a study to understand their meaning – as distinct from industrial prototypes which are constructed for practice (Koskinen & Frens, 2017). Therefore, we have sought to develop the concept of the annotated portfolio to be beneficial for UIC by using the annotated portfolio as a way of managing the overlap between research and industrial prototype construction. We consider the value of using annotated portfolios in UIC projects as broadly having value in the following ways:

1. UIC projects normally run, at a fast pace, for a number of months (this one was 10 months long). During the course of our project, close to eighty separate prototypes were produced – some representing significant evolutionary design changes and others incremental modifications. All of those investigations have some value. Without a recording system, such as the proposed annotated

portfolio method, these prototypes, the knowledge they embody and their significance to research are likely to be lost.

2. The annotated portfolio becomes a form of *knowledge* portfolio as it positions the prototypes in sequences that makes analysis of the knowledge and the practice developed via the project, transparent and transmissible. It also identifies inside the project, multiple knowledge contributions that can be potentially developed to contribute to the research focus of the academic unit. This may also help to establish a cohesive (UIC) practice, academic expertise and agency for the academic unit.

There are, however, opportunities for refinement of this method in future research. These are significantly related to the complexity associated with compiling the annotated portfolio itself. It seems necessary for the research unit to develop a system of standards to manage the vast amounts of data efficiently. The annotated portfolio ought to be compiled during the project, while connections between the academic discourse and design practice are fresh. At the same time, UIC projects are normally funded and therefore operate on a tight schedule. Based on these conditions, further research into the methods and systems for creating the annotated portfolio needs to be conducted.

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