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Reflections on Applied Design Research: A Tale of Two Theses

Abstract

This paper investigates the nature of design research in an applied context by reflecting on the authors' own experiences conducting doctoral projects with industry partners. It is hoped that with the rising importance of engagement, outreach and impact within academic research, these reflections are of interest to other researchers operating in a design research framework with industry-engaged projects.

The need for discussion of the implications of design research within an applied context has been fuelled by a recent push in academia for collaborative projects with industry. Recent CRC, CRC-P, ARC ITTC and Linkage grants reflect this drive towards industry-led and industry-engaged research, however many of these projects are predominantly led by STEM (Science, Technology, Engineering and Mathematics) related disciplines. While STEM based case-studies illustrate the challenges and success factors of the Industry-University research model, design research is a "young emerging field" and its use, implications and opportunities are therefore less understood.¹ This paper offers a different perspective, unpacking the complexity of academic relationships with industry featuring design research as a primary mode of knowledge production.

A productive relationship with industry has the potential to strengthen a research project and contribute to research relevance and impact. Insights gained from the authors' own doctoral work, carried out with a variety of industry partners within the architecture and construction fields are used to frame a discussion about the value of design research in this context. While the sample size of this paper is not extensive, it provides a foundation for future research incorporating a larger group representative of both researchers and industry partners. In this positioning paper, a critical reflective practice methodology is used to speculate on the nature of applied design research, approaches to scope definition, the importance of building trust, and the value of the client-architect relationship analogy.

Introduction

This paper reflects on the challenges of academic research undertaken in collaboration with industry partners when utilising design research methods. Recent CRC, CRC-P, ARC, ITTC

and Linkage grants reflect a push by government for university researchers to engage with industry, and increasing academic interest in collaborative models is reflected in the rise in publications about the topic over the last decade.² While practice-led design research is becoming increasingly common within the architectural field,³ there is a lack of literature on navigating applied research with an independent industry partner using a design research methodology. Current discourse on academia-industry partnerships offers a selection of case studies to illustrate the challenges and success factors of the industry-university research model, however these tend to focus on STEM disciplines and the scientific research methods associated with them.⁴ Instead, this paper offers an alternative perspective by reflecting on the complexity of academic relationships with industry which feature design research as a primary mode of knowledge production.

With an increase in funding directed at industry-university collaborative projects,⁵ this paper provides a relevant resource for architectural researchers engaging with industry, but does not attempt, at this early stage, to provide a comprehensive guide for those researchers or industry partners. As Gideon et al. note in their paper on technology commercialization and research, there is pressure on universities to “maximize the social return on public investment in research and effort to enhance universities’ self-sustenance [...] What is less clear, however, is how university–industry interactions actually shape processes and outcomes related to research and technology commercialization.”⁶ The same could be said for design research; this paper aims to provide the beginnings of a body of work on the critical reflections within applied design research which, as Christine Morley notes, “can also improve the links between theory and practice, and permits us to research ways to promote congruence between the critical aims that inspire our practice, and the ways that we actually engage in practice.”⁷

Methodology

Insights gained from the authors’ own doctoral work, carried out with different industry partners within the architecture and construction fields, frame a discussion about the value of design research in this context. A productive relationship with industry has the potential to strengthen a research project and contribute to research relevance and impact, yet is not without its challenges. This paper utilises a critically reflective methodology based on Gibb’s reflective cycle which includes descriptions, feelings, evaluation, analysis, conclusion, and an action plan.⁸ From this reflection a series of themes emerge between the two authors’ experiences. Barbara Bassot notes this type of reflective practice allows researchers to “think about [...] emerging practice at a deeper level, questioning your approach, engaging with your feelings, questioning your assumptions and gaining greater self-awareness.”⁹ Gibbs’ reflective cycle

also encourages the researcher “to think through alternative approaches and what we might have been able to do differently,”¹⁰ and speculate on the difficulties and opportunities for other researchers which may be in similar situations. The paper is structured to reflect this cycle, whereby anecdotes from the researchers’ individual experiences colour a discussion of challenges, opportunities and lessons learned throughout the process. The anecdotes below, as well as their analysis and discussion, are from the point of view of the authors without the input of industry partners. As such the accounts are likely inflected by subjectivity, despite attempts to be as objective as possible.

Throughout the paper the authors will be referred to as Author 1 and Author 2, or first author and second author. To protect the industry partners’ anonymity, the companies with which the first author collaborated will be referred to as Partners 1A and 1B, and those involved with the second author’s projects will be referred to as Partners 2A, 2B and 2C.

Background

This paper draws on the combined experiences of the authors’ doctoral research, involving two government funded research ventures and a total of five different industry partners. Despite their differing backgrounds, research interests and doctoral trajectories, the authors’ experiences of applied research with industry have many similarities. Both authors commenced their doctoral journeys collaborating with small architectural firms on separate projects within an Industrial Transformation Training Centre (ITTC) project. Both authors were drawn to an applied research doctorate as it enabled a focus on the realities and restrictions of practice, in contrast to the traditional theoretically based thesis. Coincidentally, both authors also experienced project disruption and a change of industry partner during their doctoral journeys, albeit at different times and for different reasons.

The first author’s doctoral experience involved collaboration with two small businesses during different stages of the same ITTC project. Partner 1A was a small architectural firm investigating the use of a prefabricated system for their single residential projects, and as many prefabricated housing start-ups do, the business ran on tight margins due to the capital required in establishing a factory. It was this “sink or swim” mentality which pervaded the business, in turn heavily influencing the research style throughout the early stages of the PhD. After more than a year of working together, collaboration with Partner 1A concluded due to the financial commitments of the small business. However, Author 1 was paired with a new industry partner from the same ITTC project, Partner 1B, whose researcher had pulled out of the program around the same time due to personal reasons. While the first author’s area of research loosely related to Partner 1B’s own business as a manufacturer of prefabricated

residential housing, the early phase of the engagement required new relationships and expectations to be built from perceived commonalities.

The second author's doctoral experience involved collaboration with three businesses, however unlike the first author's experience, the change of industry partners also involved a change of project. These two different engagements were of contrasting nature and scale: the first was a contained collaboration with a small architectural firm (Partner 2A) within the ITTC project already mentioned; while the second was a contribution to a much larger Cooperative Research Centre Project (CRC-P). The first project can be described as a collaboration between three people: the director of the architecture firm, the author and the author's thesis supervisor, whereas the second project involved several researchers across various disciplines and two main industry partners: Partner 2B was a large international property development and management company, and Partner 2C was a smaller subsidiary company specialising in the manufacture of prefabricated building parts. Unlike the first author's experience, this transition across projects and industry partners resulted in a shift in the focus, direction and scope of research.

Both authors approached their theses with little knowledge about industry-university collaboration, particularly when using a design research methodology. The reflections below outline some of the challenges the authors have experienced throughout the PhD journey and the resulting learnings.

Challenges and Opportunities of an Exploratory Approach

Doctoral research using an applied methodology is typically tailored to address questions and problems brought forth by an industry partner. Navigating the exploratory nature of design research in this context can become challenging if a balance is not struck between an open attitude to research focus and a loosely defined overarching trajectory that responds to the industry partner's needs.

For Author 1, the early phase of the project involved divergent exploration of various streams of research. Partner 1A was overwhelmed by the variety of possibilities within the housing industry, continually suggesting new and unrelated areas of research. Despite being passionately engaged with the work and research findings, the industry partner could be unpredictable in both their business and research interests, and after 6 months it was apparent that they would be happy to carry on this way indefinitely: touching lightly on each topic, gaining a small bite of knowledge which could be implemented within the business, and moving on to something new each week as the needs of their business changed.

This type of unstructured approach can be both frustrating and uncondusive to the rigour required for academic pursuits; it soon became apparent that a systematised approach towards focusing the topic of research was required. Each week a summary of discussions, research findings, and a plan for the next week was produced. While these summaries provided a written account of the topics covered, research outputs and developing trajectories, they failed to gain traction as a directive tool for the industry partner. This was likely due to an inability to prioritise research directives over the realities of a small business which is constantly changing. In this case it could be contended that start-up companies, though enthusiastic about new innovations and research, may be limited in their ability to be fully immersed with the research and development process.

However, this is not to say that working with an industry partner that enthusiastically chases new ideas is necessarily counterproductive to research and writing a thesis. Partner 1A's relationship to the research often produced stimulating and unexpected results when applying their pre-existing and detailed business knowledge to the theoretical concepts they were presented with. The contrast between this specialised knowledge within industry and the varied, conceptual knowledge coming out of the research had the ability to push the research questions in directions that were unanticipated from an academic perspective. This exploratory, macro research and its interaction with the micro complexities of industry at the beginning of the PhD journey provided solid background knowledge for the thesis and informed research practices continually.

Issues of Project Definition

While the exploratory approach might be useful in covering a vast range of topics and associated literature, the nature of doctoral research inevitably requires some degree of project and scope definition. The authors' experiences entail differing approaches towards defining research direction and scope within collaborative projects with industry.

Unlike the first author's experience, both of the second author's engagements were characterised by limited input from the respective industry partners. The author's interactions with Partner 2A were characterised by informal and unstructured meetings to establish the research focus and desired objectives. The author's inexperience in both research and industry-university collaboration greatly affected the nature of these interactions. Fear of directing the research away from that which was perceived to be useful to the industry partner's business inhibited significant contribution towards shaping the research direction. Furthermore, the industry partner's motives for pursuing the research were undefined.

Discussions about potential project outcomes revealed that the partner was interested in one of two research trajectories, neither of which were related to the business goals of the industry partner's own practice, making for further lack of clarity. While this type of misalignment is not necessarily detrimental to industry-university collaboration, in this case it unfortunately meant that the research was ultimately not a priority in the larger scheme of running a small business.

In contrast, the early scoping phases of the project with Partners 2B and 2C were much more formal and structured, involving weekly reporting to a project control group in written form. Although a broad field of inquiry and general objectives for the research stream had been determined at the beginning of the project, the specific focus of the research stream was ambiguous. At the time, this was perceived to be somewhat of a disadvantage due to lack of clear direction, however in retrospect, the freedom to shape the research provided an opportunity to use the specific challenges of the business as a springboard for unrestricted divergent investigation. As the research direction firmed up, quarterly presentations to the project control group provided regular opportunities for feedback and trajectory adjustment as necessary.

The first author's collaboration with Partner 1B was structured in a similar way, however this set up was perceived to be less successful in facilitating exploration of ideas beyond the industry partner's needs. Partner 1B was more refined and focused in their pursuit of achievable goals than Partner 1A. Whereas the engagement with Partner 1A had been integrated within the practice and driven by the industry partner, the new engagement was more detached, directed mostly by the thesis research. Rather than the research process being a continuous and iterative development of ideas, the monthly meetings were characterised by a structured and businesslike approach, reducing the ability for unforeseen findings. Whereas this approach gave more definition to the project, it limited the kind of discovery facilitated by industry-academic crossover in an embedded setting.

Much like the second author's experience with Partner 2A, the first author experienced issues related to lack of project definition due to the absence of perceived coherence with Partner's 1B's business strategy and goals. Whereas the research had originally been conducted with another business in mind, adapting this research without definitive goals or outcomes proved to be challenging, despite a clear overlap in interests and approaches. As a result, the research partnership was slow to progress. However, once a routine and defined roles were established, these issues resolved themselves. The experience suggests that although there may be need for *some* project definition at the outset, clearly defined roles may be more useful in allowing the scope and outcomes to be established organically.

Runeson suggests that successfully working with industry requires a delicate balance of 'pull' from the industry partner and academic 'push.'¹¹ Reflecting on these experiences supports Runeson's argument, revealing the importance of balanced input from both the industry partner and the researcher with respect to project definition and objectives. Clarity around the industry partner's motivations and their desired outcomes is important but it should not be the sole driver of the project. However, as a doctoral researcher fairly new to industry-university collaboration, it can be difficult to recognise when and how much to 'push' an industry partner. The process requires a degree of confidence which may be lacking at the beginning of a PhD journey.

Navigating the Realities of Misalignment

One of the greatest challenges in industry-university collaborative projects is the issue of misalignment. Sandberg et al believe that "although it's relatively easy to agree on challenges and goals, view-points differ regarding variables such as relevance, rigor, time horizons, planning practices, and predictability."¹² In addition to this, when working in applied design research contexts, an additional layer of complexity is inherent due to the unpredictable nature of design outcomes.

Towards the end of the second author's research project with Partners 2B and 2C a significant portion of research funding was redirected towards a large-scale prototype combining several of the project's research streams. The prototype was an unanticipated deliverable and as such it was developed in a very tight time frame. The involvement of multiple key contributors resulted in multiple research agendas and lack of clarity with respect to overall objectives. Approaches to the delivery of the prototype were not always aligned: the industry partner had significant control over these matters and consequently many aspects of the delivery were executed more like a "real" build than an experiment set up for research. The added time pressure resulted in the need for compromise and significant reduction of scope.

The prototype design process involved several intensive workshops, during which multiple ideas were put forward and considered. The most challenging aspect of this co-design process, beyond the time constraint, was the tendency of industry partner team members to limit speculative investigations with respect to practicality or their 'comfort zone' of current acceptable practice. This mode of operating is imperative for the delivery of real projects, but could be considered less productive in the pursuit of innovation. In these situations, reference to the research objectives (which Author 2 had condensed down to 3 main points) was useful as a reminder of the prototype's purpose.

Intense collaboration over a period of three months resulted in a proof of concept prototype which tested connection designs, assembly strategies and logistics tracking technologies. Although the final product would likely have been different had the project been given more time and tighter control from the academic team, the end result provided insights for all research streams involved. Furthermore, the shift in the industry partner's thinking with respect to its product line can be considered a measure of the prototype's success.

Working with Industry, Working with People

A critical aspect of research with industry is centred around the notion of collaboration, and more specifically, around developing good, trusting working relationships with people. Social skills and the ability to diplomatically communicate and solve problems are just as important as those required for the research itself. For Author 2, the early phase of the research project with Partner 2A involved working from the business premises. Despite the physical proximity, the time pressures of architectural practice combined with the director's frequent international travel meant that there was little contact time dedicated to the project. Although the discussions in the few scheduled meetings were enthusiastic and optimistic, the limited opportunity for face-to-face interaction hindered the potential to build familiarity and trust. Ultimately, this factor added to the circumstances which made it unviable to proceed with the work. The experience highlights the importance of social aspects in research projects with industry.

Wohlin et. Al found that a "researcher's attitude and social skills" are among the most important success factors in industry-university collaborations.¹³ The complexity of design research as a mode of inquiry within this context can provide an additional challenge. As part of the applied methodology in the second author's research, case studies were conducted to understand Partner 2C's primary challenges and define the boundaries of the problem space. The case studies mostly focussed on the company's products and manufacturing processes, aimed at suggesting strategies to optimise both. This process inevitably involved dissecting and critiquing existing designs. As the nature of design can be highly subjective, there were occasionally moments of defensiveness from some of those who may have had more involvement in the design process of the products being analysed. The findings of the case study work were never met with direct resistance from the industry partner, however great effort was directed towards sensitive delivery of findings.

Issues of Applied-Design Research

The authors' experiences working alongside multiple industry partners suggest that design research methodology and applied research models with industry have symbiotic qualities. Design research can be described as an unclear and problematic area which lacks definition, despite its emergence as a new research methodology.¹⁴ Ken Friedman and Nigel Cross believe there has been a "failure to develop grounded theory out of practice,"¹⁵ and that "we are still building the appropriate paradigm for design."¹⁶ What constitutes applied research is also ambiguous,¹⁷ and within design disciplines can be particularly haphazard, lacking defined boundaries. However, in the first author's experience, it was this very nature of the process that often pushed the research to an area it would not have reached otherwise. Although clearly defined goals from the outset can be beneficial for applied research,¹⁸ perhaps instigating strict deliverables at the beginning (or even middle) of the PhD research journey would have limited the opportunities for serendipitous findings which were both advantageous for both the researcher and industry partner.

Lack of Discipline Specific Guidance

Applied research within scientific disciplines is more established than in architectural design, as evidenced by the literature on the topic.¹⁹ Within these fields, existing methodologies for conducting applied research with industry partners can be drawn upon when embarking on a PhD. The literature suggests that discipline inevitably affects the nature of industry-university collaboration due discipline-specific methodological approaches,²⁰ however little has been written as to how it differs between disciplines. Rybnicek and Königgruber note that while "Scientific disciplines have different conventions and cultures, they use different methods and instruments [...] For instance, trust-building measures between industry and university partners might be more important for a project involving humanists than economists."²¹ This would imply that although doctoral researchers using a design research methodology can look to the STEM approaches for guidance, nuanced differences in the relationship may need to be addressed. As the nature of basic and applied research differs greatly, a supervisor well versed in industry-university collaboration within the design disciplines can greatly impact the PhD experience. Both accounts described in this paper have benefited from the experience and skilful diplomacy of the thesis supervisor in negotiating complicated situations during inevitable periods of change.

The Client-Architect Analogy

In lieu of the limited discipline-specific guidance for industry-aligned design research in the literature, this paper considers the client-architect relationship as an analogy for industry-university collaboration. Both applied research and architectural practice require skills beyond

those directly associated with the design or research activities, primarily social sensitivity and the ability to negotiate. In the first author's case, the earlier work with the first industry partner was a lesson in directing focus and recognising when being swayed by enthusiasm was no longer productive, while the second author's experience illuminates the risk of not contributing enough in the shaping of a project for fear of not being useful to the industry partner's business. Runeson's notion of industry pull and academic push can also be applied to the dialogue between an architect and client throughout the design and delivery process.

Continuing the analogy, both architectural practice and industry-university collaborations are heavily influenced by the nature of the professional and social relationships between the people involved. The accounts described in this paper support the view that successful collaboration with industry, despite the size of the companies involved, is underpinned by good working relationships, aligned personalities, and shared values. Due to the differing needs of business and academia in these type of partnerships, responsive and empathetic relationships based on trust are of utmost importance. Though there are differing views on the importance of face-to-face interaction in the literature,²² the both authors' experiences highlight the risks of not being able to establish social capital with the industry partner.

It could be argued that a very important difference between the two relationships lies in the researcher's obligations within their academic discipline in contrast to the architect's obligation to provide a service to the client. Despite their similarities, clarity around the transactional nature of architecture as a service is a firewall that has no direct equivalent in applied research with industry, placing more importance on the currency of trust. Industry-university collaborations using a design research methodology are further complicated by the undefined nature of knowledge production within design and the problematic division between academic output and consultancy. The ability to differentiate between the two is necessary in order to satisfy the expectations of academia and protect the confidential nature of the research subject matter when working with industry. This has been an ongoing struggle for the second author, who has been working closely with Partner 2C's products and processes. Presentations to colleagues in a university setting require abstraction of the case study work in order to protect intellectual property, which is at times difficult. If we consider the position that the knowledge produced within design research can reside in the process, design or artefact, these kinds of industry-university collaborations present a number of barriers to academic contribution. In the second author's case it was necessary to extract and make explicit findings that could sit separately to the project work itself.

Research Impact and the Perception of Failure

It is useful to consider the analogy to architectural practice when discussing research impact, which, regardless of discipline, is one of the primary arguments for applied research. The long lifespan of projects in the building industry, from conception to completion, mean that there is a delay in the physical realisation of the architect's initial design efforts. Similarly, the findings of applied design research in the built environment industry may not have any measurable impact until the next project is complete. This was the case for both authors whose research findings impacted changes in their industry partner's practices, but neither of which has seen a built outcome arise from this work to date. In this manner, proving impact, which is often a requirement of government funding, is hard to establish publicly and in the short term.

Finally, a discussion of doctoral research with industry, despite the discipline, would be incomplete without a mention of the 'failed project.' Two of the four industry engagements described in this paper were not seen through to completion, for varying reasons. Wohlin et al. found that successful collaboration with industry is influenced by several factors, which differ across disciplines and countries.²³ For Author 1, the failure of the first partnership and subsequent changes in industry-academia collaboration proved to be a large challenge to overcome. Learning from and moving beyond the original industry partner was necessary for the research to continue, and eventually the combination of inputs from both Industry Partners 1A and 1B proved to be the most successful. Similarly, Author 2 came to realise throughout the research journey that while industry partners' approaches to materials and construction may have differed, a theoretically strong overlap existed in the overarching concepts, traceable in an analysis of thesis titles from the beginning of the PhD to date.

A reflection on the experiences described in this paper reveals that terminated projects should not be perceived as failures in the doctoral research journey, despite the authors' feelings at the time. The literature that was interpreted, the research questions which emerged, and insights that were gleaned, all contribute to research trajectories and will inevitably inform the final thesis content. Additionally, exposure to the realities of change,²⁴ and the need to be adaptable within the context of applied research has helped to prepare both authors for careers in either industry or academia in a way that would not have been possible through a conventional PhD.

Conclusion

In conclusion, this paper has contributed to the limited discourse on the nature of design research in industry-university projects by reflecting on the authors' experiences as doctoral researchers collaborating with industry partners. The top four learnings for the authors are:

1. Opportunities for unexpected discoveries in the industry-university cross-over are maximised if the researcher is embedded within the industry partner's business, however this is conditional to regular contact and a good working relationship.
2. An open attitude towards divergent exploratory investigation and regular discussion around research trajectory are highly important.
3. Design research is suited to complex and interdisciplinary problems, and defining the scope of applied research too early within the project can limit the holistic abilities of the methodology. Ideally, there should be a balance between an open attitude to research focus and a loosely defined overarching trajectory that responds to the industry partner's needs.
4. The analogy of the client-architect relationship is useful both useful and problematic in applied design research. Where architects may be tempted to return to the comfort of this role as a service provider, there is a risk of not creating impactful research.

The four industry engagements described in the paper have been compared and contrasted as a way of unpacking the complexities of design research methodologies in an applied research context, and it is hoped the prevailing analogy of the client-architect relationship provides a useful insight to the dynamics of industry collaboration in the design fields. While this paper raises many questions, it does not provide a comprehensive guide. Instead this paper positions itself as a springboard for future investigation of applied design research within the architectural discipline, with the potential to incorporate a larger cross-section of researchers with a wider range of experience, as well as a selection of industry partners. It is hoped that the reflections within this paper can be further built upon to provide a more extensive suite of findings for future researchers and industry partners working with applied design research methodologies.

¹ Murray Fraser, *Design Research in Architecture: an Overview*, (Farnham, UK: Ashgate, 2013), 4.

² See: Robert Rybnicek and Roland Königsgruber, "What Makes Industry–University Collaboration Succeed? A Systematic Review of the Literature," *Journal of Business Economics* 89, no. 2 (2019): 228; Igors Skute et al., "Mapping the Field: A Bibliometric Analysis of the Literature on University–Industry Collaborations," *The Journal of Technology Transfer* 44, no. 3 (2019): 916–47.

³ This practice-led design research is evidenced in the doctoral degrees by Monash and RMIT Universities in Australia.

⁴ See: Per Runeson, "It Takes Two to Tango - an Experience Report on Industry-Academia Collaboration," *2012 IEEE Fifth International Conference on Software Testing, Verification and Validation*, April 1, 2012, 872–77, doi:10.1109/ICST.2012.190; Toke Bjerregaard, "Industry and Academia in Convergence," *Technovation* 30, no. 2 (January 13, 2010): 100–108.

⁵ Amro Tambal, "Industry, Academia, and Government Working Together," *Chemical Engineering Progress* 113, no. 8 (August 2017): 16.

⁶ Gideon D Markman, Donald S Siegel, and Mike Wright, "Research and Technology Commercialization," *Journal of Management Studies* 45, no. 8 (December 2008): 1401–23.

⁷ Christine Morley, "Critical Reflection as a Research Methodology," in *Knowing Differently*, (New York, 2008), 148–63.

⁸ Graham Gibbs, *Learning by Doing: A Guide to Teaching and Learning Methods*, (Oxford: Further Education Unit, Oxford Polytechnic, 1988).

⁹ Barbara Bassot, *The Reflective Practice Guide : an Interdisciplinary Approach to Critical Reflection*, (Oxon: Routledge, 2016), xi.

¹⁰ Bassot, *The Reflective Practice Guide*, 72.

¹¹ See Runeson, "It Takes Two to Tango - an Experience Report on Industry-Academia Collaboration," 872-77.

¹² Anna B Sandberg, Lars Pareto, and Thomas Arts, "Agile Collaborative Research.," *IEEE Software* 28, no. 4 (June 2011): 74–83.

¹³ Claes Wohlin, Aybuke Aurum, Lefteris Angelis, Laura Phillips, Yvonne Dittrich, Tony Gorschek, Hakan Grahn et al. "The success factors powering industry-academia collaboration." *IEEE software* 29, no. 2 (2011): 67-73.

¹⁴ Hélène Frichot, "What matters? Who cares? How? And the ability to venture what if?," in Jules Moloney, Jan Smitheram, and Simon Twose (ed.), *Perspectives on Architectural Design Research*, (Baunach, Germany: Spurbuchverlag, 2015), 194.

¹⁵ Ken Friedman, "Theory Construction in Design Research: Criteria, Approaches, and Methods," *Design Studies* 26, no. 6 (November 2003): 519.

¹⁶ Cross, "Design Research: a Disciplined Conversation," 10.

¹⁷ Michael D. Reagan, "Basic and Applied Research: A Meaningful Distinction?" *Science*, Vol. 155, no. 3768 (Mar. 17, 1967), 1383-1386.

¹⁸ Terry E. Hedrick, Leonard Bickman, and Debra J. Rog, *Applied Research Design: a practical guide*, (Newbury Park: Sage Publications, 1993), 15.

¹⁹ See: Hedrick, Bickman, and Rog, *Applied Research Design*.

²⁰ See: Rybnicek and Königsgruber, "What Makes Industry–University Collaboration Succeed? A Systematic Review of the Literature." 239; Taran Thune, "Doctoral Students on the University–Industry Interface: A Review of the Literature," *Higher Education* 58, no. 5 (2009): 642.

²¹ Rybnicek and Königsgruber, "What Makes Industry–University Collaboration Succeed? A Systematic Review of the Literature." 238-239.

²² Rybnicek and Königsgruber, "What Makes Industry–University Collaboration Succeed? A Systematic Review of the Literature." 231.

²³ See: Claes Wohlin, Aybuke Aurum, Lefteris Angelis, Laura Phillips, Yvonne Dittrich, Tony Gorschek, Hakan Grahn et al. "The success factors powering industry-academia collaboration," 67-73; Rybnicek and Königsgruber, "What Makes Industry–University Collaboration Succeed? A Systematic Review of the Literature." 238-239.

²⁴ Runeson, "It takes two to tango", 876