Design research methods and methodology: a mini review and possible future directions

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Abstract

This paper completes a short review of design research methods and methodology before commenting on possible future research directions for the design community. As such, the paper is aimed at two primary audiences – student researchers who may be made aware of some options within their field, and the community at large, in order to stimulate discussion and development. After the presentation of four design research methodologies and design research methods characteristics, the paper concludes by presenting the 'path to success' model, a simple representation which may be adopted to progress appropriate research in the design field.

1 Introduction

This paper discusses research methods and methodology from the engineering design field using both UK/European and US perspectives. The paper has two main intended audiences: first, in providing a short summary of available methodologies and methods student (particularly Doctoral) researchers may become better informed as to the options open to them. Second, by commenting on possible future directions, as well as increasing the awareness of world-wide approaches, it is hoped that the design community at large may be stimulated to increase discussion and development within the research methods/methodology domain.

Highlighting the usefulness of such content to each audience is worthwhile. In the case of student researchers it is widely appreciated that the first degree (US also?) does not prepare one for a career in research. Although a PhD may rightly be considered as an 'apprenticeship' for doing research, more guidance and higher levels of pre-preparation may result in a greater degree of research projects which can be shared within the community, through being valid and useful. Furthermore, the community at large is in need of increasing the level of rigour. Elements that may seem obvious are often omitted – Blessing (ref) reports on findings from Cantamessa (ref) which found that of 111 papers on empirical studies in two ICED (International Conference on Engineering Design) conferences 10% did not state the research approach, 22% did not give the unit of analysis, 41% did not state the sample size and 25% did not state the implications of the findings. These omissions lead to research which, at best, is hard to understand or re-use and, at worst, simply invalid.

The paper is structured as follows: part 2 briefly presents the background and motivation in terms of design and design research. This is followed by a foundation section for the paper, differentiating research methods and methodology. Part 4 then details four design research methodologies, 2

each from the UK/Europe and the US. Part 5 details research methods for design and is followed by a summary section which discusses challenges and future research directions.

2 Background and Motivation

What is design and design research?

Design is the activity involved in the development of an artefact or part of artefact from idea to manufacturing hand-off. Essentially, design (in best practice) is about fulfilling human needs and, particularly through the link with innovation, can make a real difference to quality of life.

Design practice, in having the potential to significantly leverage innovation activity, should be of greater interest on an organisational level. Yet in many companies design is not 'championed', in some places inexplicably where innovation is preached as being the ultimate aim. If innovation is the value-added exploitation of ideas, design activity has the potential to make many of those ideas reality.

In order to increase the influence of design an understanding of design product and process must be developed. First, much company activity concerns the development and creation of products – this is often the bottom line for creating wealth. Second, the nature of the design process, in being a divergent and convergent development of ideas may be used in other activity. Many fields address a brief/problem/need by evaluating options to create a solution. In summary, the design perspective may be successfully employed and extended on a company level with innovation as the common factor.

Improving research methods and methodology and hence the scientific basis of design research within the community is a key step to enabling this transfer. Design research has the ultimate aim of improving design practice. It follows that there is two natural streams for this to happen: – understanding practice (which may also be termed reality, description or AS-IS) and changing current practice for the better, (also termed envisaged reality, prescription, or TO-BE). Since there is no community standard or much developed theory regarding design research methods and methodology (as demonstrated most notably by Cross [ref) greater community discussion and development may ensure that success criteria for design research - validity, practicality etc – is input to result in more sharing, re-use and community growth.

3 Defining/differentiating methods & methodology: philosophical foundations

Before presenting examples of design research methods and methodology it is worthwhile defining each element and differentiating the scope of each. Both terms are often used interchangeably to the detriment of community understanding and development. Simply put, methodology is the overall system of methods and constituent elements implemented as a holistic approach for a piece of research or constituent task (such as data

collection). A method is a systematic procedure for accomplishing a task and represents a focused action within the overall methodology.

A simple way of modelling methods and methodology is shown in figure 1 below. Where methodology represents guidance for the overall research 'journey' from starting brief to documentation, methods are used at points along the journey to facilitate research actions. These supporting mechanisms, such as literature review, laboratory experiments and case studies are used to source data and often have an element of empiricism from design practice.

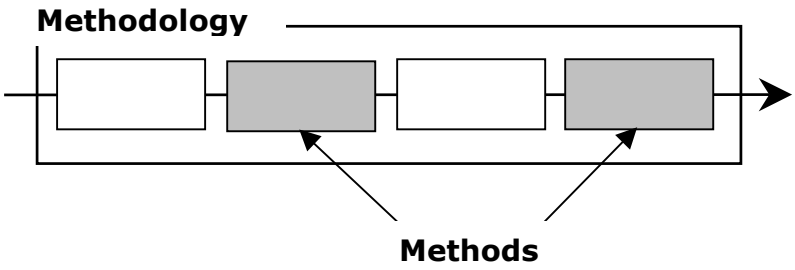

Figure 1:Research journey with methods shown as point actions

It is possible to further model this journey by adding basic elements, standard actions that any research project should include. Figure 2 shows these, with the research core (review of research brief and testing of hypotheses) the very least necessary for any research endeavour. Methods are shown to take place mostly at the review and hypothesis testing stages.

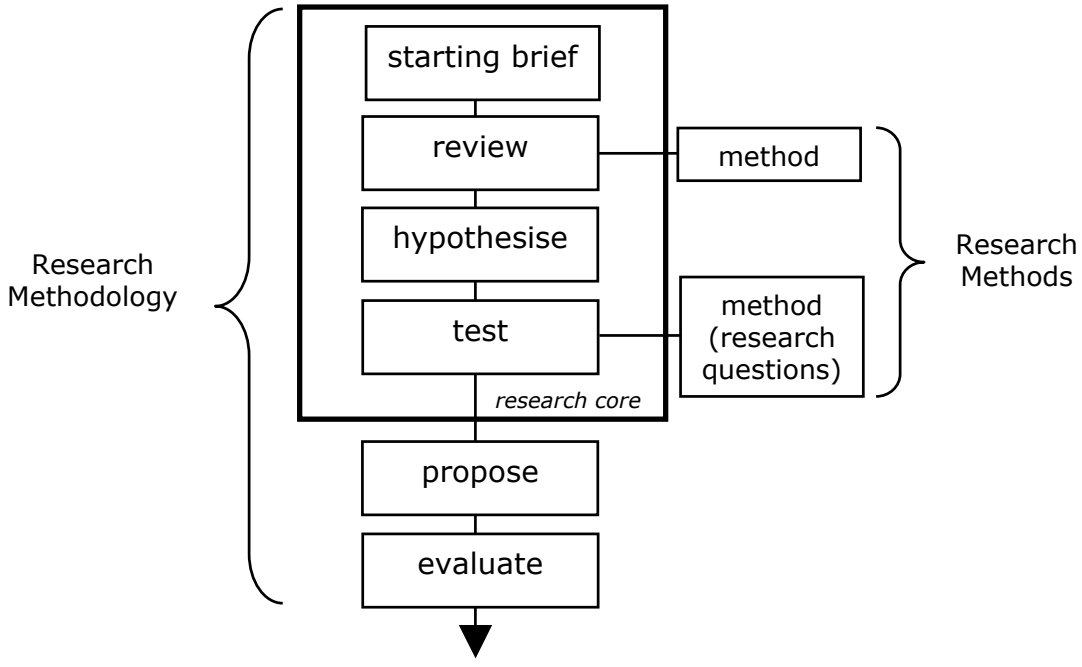

Figure 2:

Examples of design research methodology, the overall framework within which a project may be tackled, are now presented.

4 Design research methodology

Four examples are presented and briefly discussed, two within the UK/Europe domain and two from the US.

Blessing model (Technical University of Berlin, Germany)

The descriptive based model from Blessing is based on a fundamental understanding of design research, discussed in section 2, of having a descriptive and prescriptive element. An initial descriptive study is followed by a prescriptive study and a second descriptive study. Prior to this descriptive/prescriptive core is the success criteria stage which specialises the methodology for design, prescribing the definition of criteria which defines the success of design, such as time to market. This allows some element of measurement in the research and links closely to design practice.

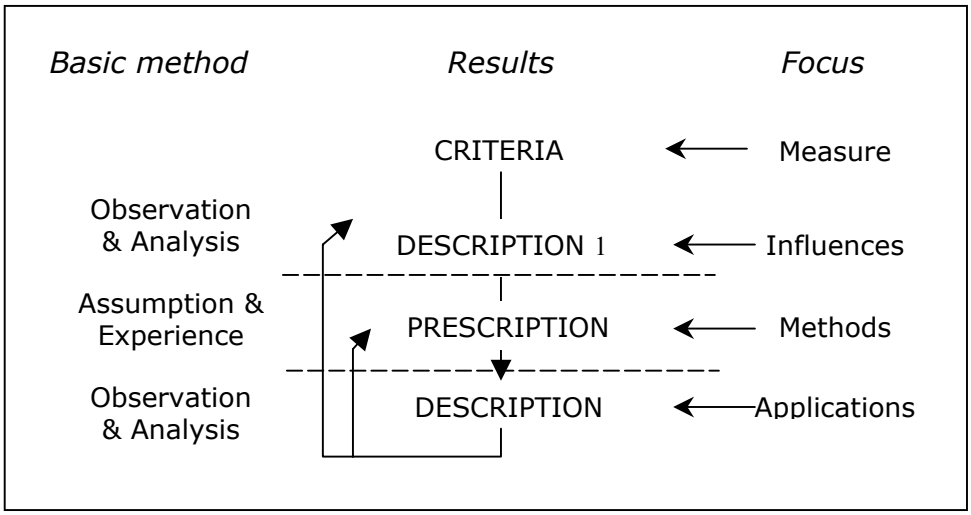

Figure 3:

The model also includes links believed to be missing in much design research, calling for their inclusion to increase scientific rigour. These include the creation of prescriptive work in relation to an initial descriptive study (1), the evaluation of the use and implementation of the prescriptive work (2a) and the evaluation of the effect of prescriptive work on current practice (2b).

Finally, the model shows the complete research cycle yet not all stages need be completed with the same level of rigour. This is particularly instructive for Doctoral projects which often have a 3 year timeframe. Table 1 below details some options for each stage.

Table 1: some level of detail options in the Blessing model

Criteria	Descriptive Study 1	Prescriptive Study	Descriptive Study 2
Review	Review	Detailed	Initial
Review	Detailed	Initial	

Center for Design Research (CDR) model (Stanford University, US)

The CDR model is an iterative cycle of observation, analysis and intervention. It is a simple representation yet powerfully defines the main steps in a research project, inherently including some of the 'missing links' identified by Blessing. For example, by closing the loop and observing the result of interventions one may satisfy link 2b – evaluating the effects of prescription on practice.

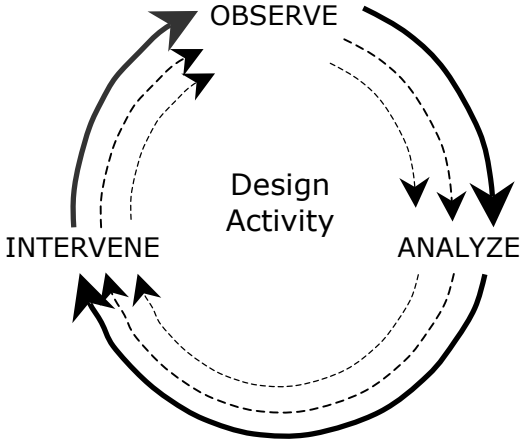

Figure x: CDR research methodology (originally from Tang x)

Three iterations of the observe – analyse – intervene cycle are advocated. This guarantees rigorous research but can lead to long studies, normally not possible within the 3 year framework recommended for UK based PhD´s.

Furthermore, each part of the cycle may be completed with varying degrees of detail, similar to the research options highlighted by Blessing in Table 1. Figure x below shows the approach taken by Eris, communicating decreasing levels of observation and increasing levels of analysis and intervention as the research proceeds.

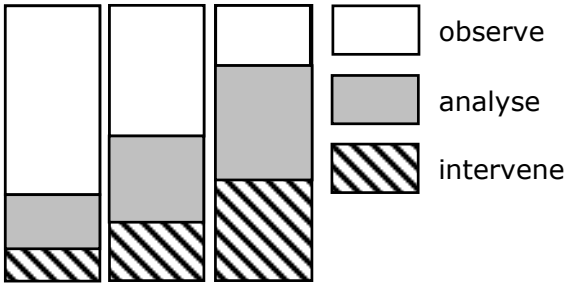

Figure x: (Eris)

Inherent within the CDR approach is the availability of scientific instruments – most notably the use of the design observatory (ref), which increases the rigour and exactness of experiments, often using design students as test subjects. However, as will be presented in the methods section the exactness of laboratory experiments includes a trade-off with low realism

and generalisability. Furthermore, the study of design students may need to be combined with some element of design professionals observation in their natural setting. To this end, the three iterations of the cycle can be used to provide a combinatory approach which satisfies these trade-offs and ensures validity.

CAD Centre model (DMEM, University of Strathclyde, Scotland)

Again based on the fundamental research elements of description and prescription, the CAD Centre model was created for an Artificial Intelligence in Design (AI in Design) context. Description and prescription are represented by the terms reality and envisaged reality.

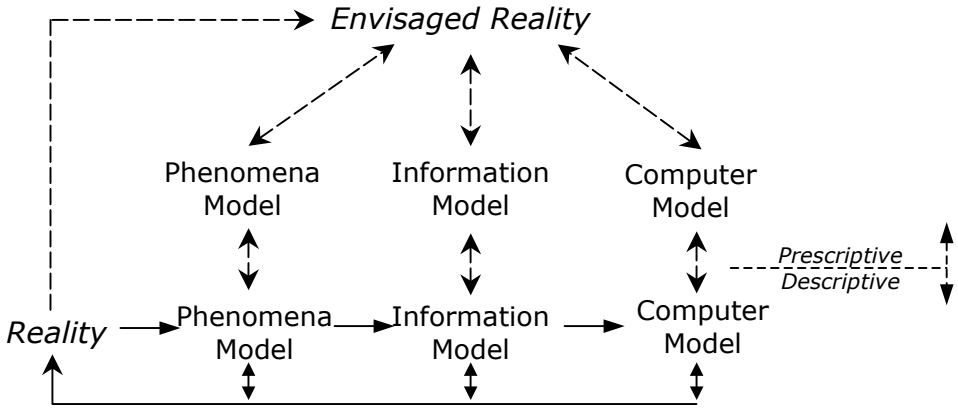

Figure x:

The model is termed a framework as opposed to a methodology as the researcher can start at any point in the model, facilitating the re-use of work from past projects. By inputting a starting point, at any point of the description or prescription, the model becomes a methodology and defines a plan of action for research.

Defining characteristics of the model include the evolutionary modelling aspect in both the description and prescription paths, which fits the notion of design research. From phenomena model to computer model there exists *increasing concreteness* which may reflect the development of ideas within a research project. Although created for AI in design, it is possible to adapt the model for other contexts. For example, MacGregor (ref) substituted processes and methods for computer model in his thesis on distributed design process management.

n-dim model (Carnegie-Mellon University, US)

The *n*-dim model provides an interesting contrast with previous models, addressing the great need for increased practicality and use in design research by focusing on the development of support tools in industry.

Included in the model are iterative cycles of description and implementation (top half) and evaluation/maturation of design tools (bottom half). The

prescriptive element, present in previous models is manifested here in the creation of the support tool leading to mature technology/support.

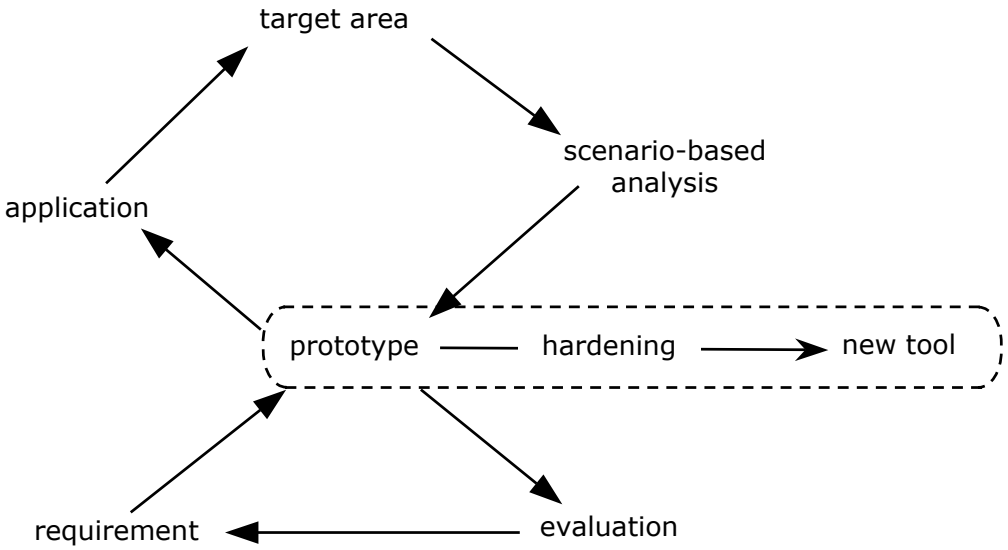

Figure x: n-dim model for creation of design support tools

Challenges within such a tool/industrial centric model include retaining a valid academic contribution once the needs of industry have been taken into account. Furthermore, for complete validity it may be necessary to include some element of gauging interactions or implementation of the new tool.

Few academic projects adequately bridge the divide between research and practice, efficiently completing technology transfer. It proves difficult to initiate and sustain relationships on the academic/industry interface. Evolved research methodologies may help in this respect.

5 Research methods

Now that a grounding has been established by presenting some models of design research methodology, it is appropriate to detail research methods. The overall research methodology can be rigorous yet if methods are ill-conceived the whole research can become invalid. To re-iterate this second part presents mechanisms which facilitate actions along the research journey, in an attempt to raise awareness of options, elements and challenges. Specifically, elements of observation and intervention will be highlighted.

The community status of methods is similar to that of research methodology – there is no standard and probably even less specific instruction available for design. This is particularly damaging to the progress of young researcher programmes. Again, considerations of validity, practicality and context need to be highlighted with some discussed here.

What options do we have?

First, it is useful to summarise some of the options open to the design community. Foltz (ref) recently reported on the McGrath circle which summarises methods and characteristics as shown below in Figure x.

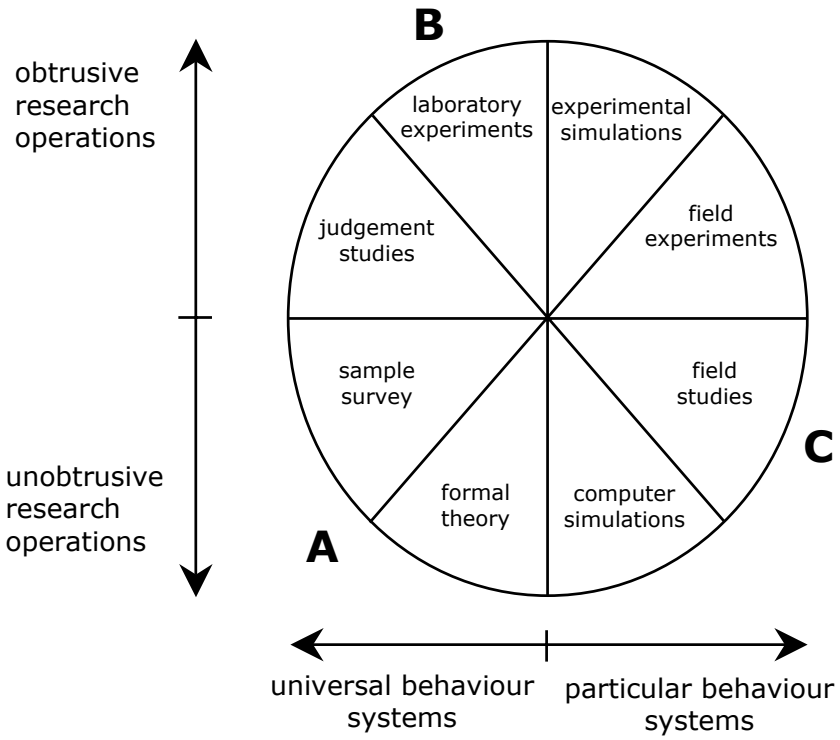

Figure x: mcgrath

As shown eight types of methods are divided into four pairs, depending on their characteristics. In the upper right section experimental simulations and field experiments are characterised by being obtrusive operations and particular to the area being studied. At the bottom right, field studies and computer simulations are also particular to the area being studied but are unobstrusive. The remaining four methods are characterised as shown. Although some terms are different from the usage in the design community the representation is useful in terms of content and classification.

The strategic dilemma of research methods

Each of the characteristics show the trade-offs inherent in picking a specific method – this strategic dilemma is addressed by McGrath and is shown by the annotations A, B, and C on figure x. As stated by Foltz (ref) It is not possible to simultaneously maximise the three major goals of research evidence, the g*eneralisability* of evidence over *populations* of actors, the *precision* of measurement of *behaviour and the realism* of situation or *context.* In summary:

- Field studies gain realism (C) at the price of low generalisability (A) and lack of precision (B),

- Laboratory experiments maximise precision of measurement and control of variables (B), at the price of lack of realism (C) and low generalisability (A),
- Surveys have high generalisability (A) but get it by giving up much realsim (C) and precision (B).

Addressing the strategic dilemma

This dilemma may be addressed in two ways – for example, as shown in the CDR model different cycles or iterations of research operation may be employed to balance trade-offs. First, however, the context of the research project must be examined in order to define the most suitable method. Yin (ref) provides basic guidance for examining context, through defining operational characteristics of specific methods or strategies. Finding the best fit for a research project may be one possible application, yet theoretical extension within the design field is first required.

Table x: YIN

STRATEGY	FORM OF RESEARCH QUESTION	REQUIRES CONTROL OVER BEHAVIOURAL EVENTS?	FOCUSES ON CONTEMPORARY RESEARCH?
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival analysis	Who, what, where, how many, how much	No	Yes/no
History	How, why	No	No
Case study	How, why	No	Yes

Community characteristics

In order to gauge the appropriateness of the social science base and define a starting point for community research, it is first necessary to define the present characteristics of the design community.

Although overlaps exist, a useful classification of design studies application and context may be as follows:

- Observation based studies,
- Case-studies

Observation-based studies

Hales (ref) briefly summarises the characteristics, advantages and disadvantages of different observation based methods, himself using participant observation in early 1980´s UK industry.

In **direct observation**, the researcher remains as unobtrusive as possible, recording what happens without taking part. This has the advantage in that the field work is wholly devoted to gathering data. However, the observer is one step removed from the process under study and may miss certain key elements in the analysis or incorrectly view the actions being observed. One example is the study from Marsh (ref) who observed engineers working

daily in an automobile firm, recording the time in minutes that designers spent sourcing varying pieces of information and the actions involved. Such direct observation was supported through other methods, including interviews, to address some of the limitations already discussed.

In **participant observation**, the researcher takes part in the activity, at the same time observing and recording events as they occur. In this manner more subtle aspects can be explored, helping to reduce distortion as the researcher becomes party to 'group-think'. However, the field work is divided between the job and recording while data is more likely to be affected by bias, through working on the project. Further problems include:

- gaining entry to the group,
- establishing social identity to enable relationships,
- fitting in with natural flow,
- remaining objective,
- developing reliability in recording, and
- knowing when to finish and leave.

As mentioned, Hales (ref) used this method to good effect becoming part of a design team in the development of a gasifier test rig for British Gas. However, Dr. Hales had previous experience as an engineer and the participation lasted for 3 years – two factors which would exclude many researchers in the design community, particularly Doctoral students.

Finally, **action research** involves the researcher as complete participant, actively planning to influence the whole situation. This can be used to experiment with new approaches for carrying out an activity and is suitable for testing hypotheses, potentially fulfilling misiing link x in the Blessing model. Therefore, it has the advantage of being focused research allowing feedback on evolved judgements, yet is open to even greater bias and low generalisability. An example from the design community includes

Summary of options

All options regarding observation based studies are listed below. Each factor should be considered by the researcher when examining the context of the research project and designing the overall approach to data collection.

open v hidden:
Can the observer or technical instrument be perceived by the test subject? Research has shown that behaviour can be affected when test subjects know they are being observed. In many cases, however, hidden observation will not be possible.

participatory v non-participatory:
Does the observer take part in the situation? This has been detailed above with 3 types of studies typical in the design community on the participation/observation scale.

standardised v non-standradised

Is the observation structure well-defined or explorative? Depending on the type of research being carried out, whether exploratory or focused methods may include highly defined or very open questions.

artificial v natural situation
Observed situation designed solely for investigation? For example, a project may be specifically designed to test research questions or studies may take place within normal day-day activities.

academic v industrial context
Design practice or design education domain?

Case studies

Yin (1994) defines the case study as:

"an empirical inquiry that investigates a contemporary phenomenon within its real life context"

As stated in table x case studies are usually preferred for asking "how" and "why" questions when there is little control over events. They come in three main forms depending on the type of research questions being asked and maturity of the research propositions including:
Explanotory – used to establish theories
Exploratory – used to explain some hypothesis or belief
Descriptive – used to gain an insight to practice

Specific cases may be further differentiated by the amount of cases and units of analyses, the exact phenomena being studied (in both cases single v multiple). In all cases, such considerations should be combined with critical elements to specify the research design. The main elements include:

- The questions
- The propositions
- Unit(s) of analysis
- Logic linking data to the propositions
- Criteria for interpreting the findings

Each element should be specificed and recorded in a formal document for use of all researchers and subjects involved in the study. This case study protocol is the primary preparation document for conducting the case and critical for success.

Further elements worthy of highlight are now discussed.

Multiplicity of methods

As discussed, using more than one method is necessary to provide a balanced set of results, while addressing the context in a project and the limitations of certain methods. Commonly used methods in the engineering design field, evident in studies from MacGregor (ref), Jagodzinski et al. (ref) and Schaub and Frankenberger (ref) include documentation analysis, direct observation, interviews, questionnaires, and diary analysis. Figure x below

shows the data triangulation representation from Yin, using a multiplicity of methods to confirm facts.

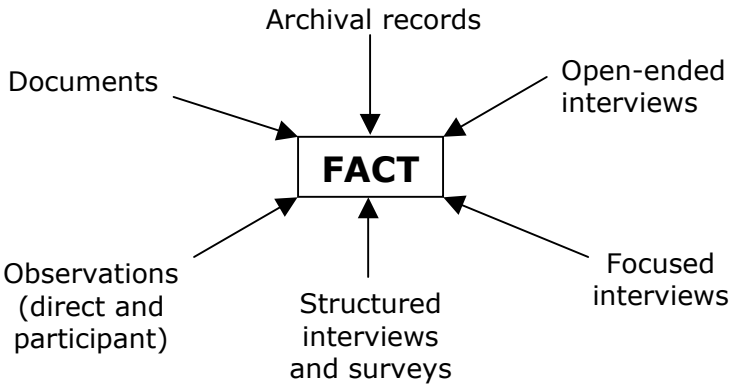

Figure x: data triangulation yin

Finally, Yin (ref) summarises validity considerations for research designs, defining where and how they may be successfully catered for.

Table x: validity considerations yin

TESTS	CASE STUDY TACTIC	PHASE OF RESEARCH IN WHICH TACTIC OCCURS
Construct validity	- use multiple sources of evidence - establish chain of evidence - have key informants review draft report	data collection data collection composition
Internal validity	- do pattern matching - do explanation building - do time-series analysis	data analysis data analysis data analysis
External validity	- use replication logic in multiple case studies	research methodology
Reliability	- use case study protocol - develop case study database	data collection data collection

6 Summary and Considerations

Methodology

The methodology section showed appropriate and useful models for structuring design research, raising elements for consideration and implementation. Each model has good elements - it is likely that each one may be used for different contexts, while the many comminalities evident inform on core elements for a design research endeavour. For evaluation and implementation it may be useful to have an evaluation framework similar to Yin in order to choose the best fit for a project or set of constraints.

The models are also flexible, allowing use of previous studies within ones own research. However, this is where part of the problem lies – in having no established theory of design and few accepted rules/findings, many

research projects end up creating their own descriptions and have little time to complete the research cycle, prescribing and (even less) evaluating changes to the design process. This is related to the traditional problem of undergraduate design programs where young designers with few experiences, repeatedly work on the front end of design and conceptual stages without gaining expertise in real detailed design. It is clear that a balance is required to progress effective prescriptions and evaluate intervention.

Methods

Regarding methods, many options are open to the design researcher, yet all include limitations. Consequently, a combinatory approach should be taken to balance these trade-offs. Additionally, there has to be an awareness of the characteristics of each and a mapping to ones own project context. Design studies are shown to involve some level of observation or intervention with examples given of previous work in the design community using case studies and the three types of observation based study. However, more of a design centric theory base and an appreciation of the specific opportunities and constraints of design studies is required. This, and other factors are discussed below.

Future directions and challenges

In light of this short review there exists the following points for discussion regarding community development:

- Terminology. Research methods and methodology exist on different scales which can cause confusion if not defined and explained in detail. These include the research framework level, research operation level and data collection level. A clearer definition of each may help and could come as part of an integrated model of design research operations.
- Design research theory. In the same way that Yin provides straightforward guidance for examining context and validity (among other aspects) basic design rules should be created to make the social science base more appropriate.
- Integration. Some of the work on methods and methodology has overlapped, such as the advocation of multiplicity of methods and the CDR iterative research cycle. One possible means of progression in the design field would be to make more of an explicit link between research methods and methodology. For example, link 1 in the blessing model should be conducted through action research in natural settings. Such research 'road-mapping' would be particularly useful for young researchers.

The means by which these avenues could be explored needs to be identified. A key point for leverage is design education, improving the practice of young researchers to ensure sustainable development and success. However, elements have to be put in place before this can happen at the required level, including the development of communities of practice (CoP´s) and a design theory base. These issues are represented in Figure x below – the path to success model. By improving education and then

ensuring that all researchers 'do it right', more areas of industry may be convinced of the worth of design research, which in turn, feeds the design theory base.

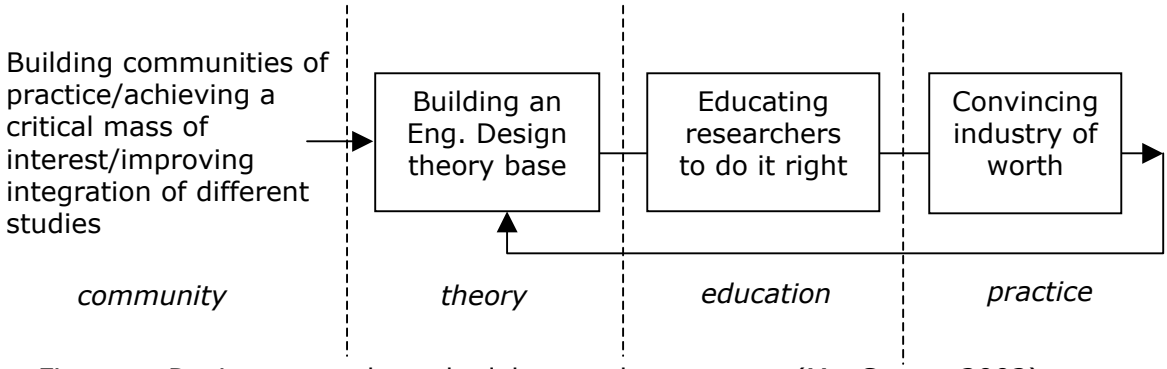

Figure x: Design research methodology path to success (MacGregor 2002)

As shown, figure x includes elements of community, theory, education and practice. Figure x below shows these as an evolutionary model, each level drawing on a mature basis of the preceding one. The model, existing as it does on a sufficient level of generalisation, could be extended to other endeavours in the design community. The current level of development for design research methods and methodology is shown below, as building design community.

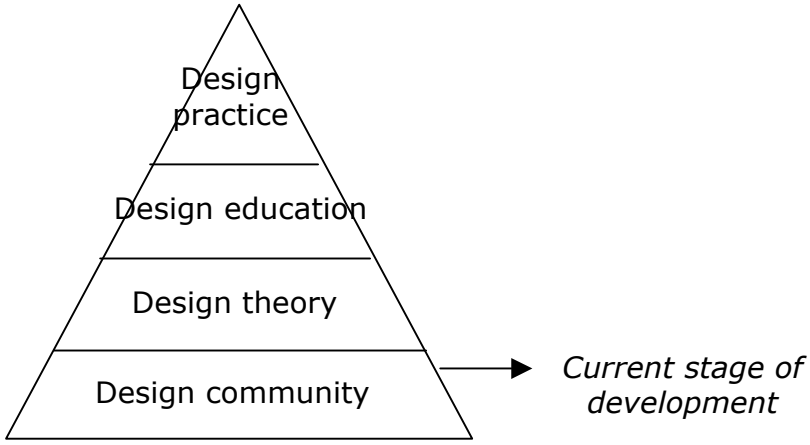

Figure x: Necessary maturity levels

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