Understanding Methods: Mapping the Flow of Methods, Knowledge and Rigour in Design Research Methodology

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Abstract

This paper focuses on how methods and knowledge link within the methodological flow of research. This focus is related to one of the key requirements of research, the contribution to knowledge. The research identifies and analyses different types of methods and explains the role of individual methods within the methodological flow and in relation to knowledge. Bringing together a number of different factors in this regard, the paper develops a framework, which extends the one proposed by Niedderer and Imani (2008) to include the relationship between methods, knowledge, and rigour.

The outcome of the research is an overview of different types of methods, and a framework for mapping the flow of methods and knowledge through the stages of research, which is illustrated through an example of its application. The contribution is an enhanced understanding of how different types of methods can be used within the flow of research. The benefit to help researchers choose more deliberately which methods to use at which stage and for what purpose.

Key words: Design Research, Methods, Methodology, Knowledge, Rigour

1. Introduction

This paper focuses on how methods and knowledge are linked within the methodological flow of research. This focus arises from one of the key requirements of research in the UK and elsewhwere, the 'contribution to knowledge', which means an addition to knowledge that is new, not just for one person (e.g. the researcher) but altogether for the field. Methods in turn are the pragmatic vehicles of research to achieve the contribution to knowledge, because they have a central role in how we integrate, generate and communicate knowledge in research (Niedderer and Imani 2008).

The aim is to identify and map different types of methods according to their characteristics and role in research. In order to do so, it is necessary to look at how the understanding of knowledge influences the understanding of rigour in terms of research conduct and hence of the use of methods. The aim for this research was sparked by historical developments of research in the UK where, over the past two decades, design research has emancipated itself from traditional humanities and engineering based research. From this emancipation uncertainties arose about how to conduct research that is appropriate to, and relevant for design research because the requirements of research remained the same, but the needs of researchers changed (Niedderer 2009, Niedderer and Roworth-Stokes 2007). These needs are related to the importance of experiential knowledge in

design, and expressed through the wish to use creative practice as part of research.

One key question that arose from this development was how **experiential knowledge** can be integrated and communicated in research in relation to the requirement of the **contribution to knowledge** in a way that promotes quality and equity in research, and how the application of methods changes with the changing understanding of knowledge, and **rigour**. In the following, I discuss these three key concepts and their relationships, before explaining the approach taken in this paper.

Experiential knowledge (also: non-propositional knowledge) in general is regarded as knowledge derived from experience, although there are variations (e.g. Williams 2001: 98, Grayling 2003). Experiential knowledge is perceived to be important for designers, because it can provide data, verify theoretical conjectures or observations etc. While experiential knowledge can be described, some part of it evades communication and remains tacit. It is therefore also termed 'tacit knowledge'. Because of its (partly) tacit nature, experiential knowledge does not easily yield to practices of justification and evidence traditionally used in research (Williams 2001: 98; Niedderer 2007b:7).

Justification and evidence are key elements of the understanding of knowledge, and the **'contribution to knowledge'** in research. The position of knowledge that is implicit in research through regulations and requirements prioritises what is known as propositional knowledge (Niedderer 2007a). The concept of propositional knowledge is defined as "justified true belief" (Grayling 2003:37), and is characterised by the 'proposition' or 'thesis' ("true belief") on the one hand, and the justification through adequate evidence on the other. The need for explicit justification traditionally requires all parts, and thus knowledge, to be explicit and generalisable (Niedderer 2007a). Most research regulations, especially for PhD's, prescribe a set of requirements to meet these standards (e.g. AHRC 2008: 24; RAE 2005; as well as many university research definitions worldwide e.g. Curtin University of Technology 2001: 2, 3; Indiana University Southeast 2005: 19, 50).

Comparing these two positions on knowledge, one example is the description of the experience of touching metal. We can describe individual aspects such as coldness, smoothness, etc, but this is not the same as the total complex experience of 'metal-ness', and no description will communicate this to someone who has never experienced it. Therefore the description remains un-evidenced unless accompanied by the physical experience. Another case is that of skill, which can never be fully communicated, because "we can know more than we can tell" (Polanyi 1967: 4).

The particular understanding of knowledge in research is related to a particular understanding of research conduct, termed **'rigour'.** The idea of rigour in research has developed to achieve equity in terms of research conduct and quality across different disciplines, projects, etc. Rigour is understood as intrinsic logic or causality embodied through "the chain of reasoning" (Gorard 2002; Freeman 1990; Millo, Lipton and Perlis 1979). Rigour has at times been disputed as a criterion of positivist science. However Tobin and Begley (2004: 390) argue that rigour is a criterion that transcends individual paradigms:

> Rigour is the means by which we demonstrate integrity and competence (Aroni et al. 1999), a way of demonstrating the legitimacy of the research process. Without rigour, there is a danger that research may become fictional journalism, worthless as contributing to knowledge (Morse et al. 2002). However, in response to Morse's caution, we suggest that qualitative researchers are not rejecting the concept of rigour, but are placing it within the epistemology of their work and making it more appropriate to their aims.

In this sense the notion of rigour can pertain to both scientific and philosophical, positivist and constructivist, quantitative as well as qualitative study. Its parameters will vary dependent on the paradigm of study (Hamberg et al 1994; Tobin and Begley 2004). While traditionally the parameters of rigour are validity, reliability, objectivity, and generalisation, for qualitative research they may be re-interpreted as credibility, dependability, confirmability and transferability (Hamberg et al. 1994: 178). Thus paradigms determine which knowledge framework is employed in general, while rigour offers tangible criteria for linking methods and knowledge.

In summary, this research seeks to clarify how we can identify and characterise different types of methods for use within design research, and how their application changes with different understandings of knowledge and rigour. In order to do so, this paper discusses models of research as the parameters that determine the choice and use of methods with particular reference to design. It proposes a framework for mapping the flow of methods and knowledge, reviews different types of methods with regard to this framework. It finally offers one case study to demonstrate the application of the framework.

2. Methodologies: Connecting Methods and Knowledge

Having established the interrelated concepts of knowledge and rigour in the context of research, this section examines the question what might distinguish design research from research in other disciplines, e.g. history, philosophy, or engineering. The aim is to identify characteristics of design research and their methodological implications.

This question has arisen historically, because design has been recognised only recently as an academic research discipline. Previously, any research relating to design had to be conducted in an established research discipline such as history, philosophy, education, or engineering. This has brought methods and methodologies from these disciplines into design research. While this is not a problem in itself, for many design researchers it has been difficult to identify with the established positions that are 'imported' together with methodologies from those disciplines. This is because the established positions (and thus their contributions) remain bound to their disciplines, rather than making a genuine contribution to design. For example, using a firmly historical or philosophical approach is unlikely to deliver results that contribute to the development of design or its understanding, unless integrated in an appropriate design research methodology. This means, the interest here is not in studies of critical discourse about design as a historical or cultural phenomenon as can be found in studies of history or material culture, but in studies that advance the field of design from the perspective of design.

The recognition of design as an autonomous research discipline means that it is driven by its own discipline-specific aims, which characterise it. This aim is ultimately the contribution to (knowledge of) creative and professional design practice, which also drives the understanding of whether the use of any (set of) methods is rigorous, because it determines the choice of approach (theoretical model), what methods are used, and how and why they are used. The idea of discipline specific research has introduced the use of design practice as part of design research. Over the last two decades several studies have been concerned with the development and use of design methods within and for design research. Publications by Cross (1984, 2001, 2003) have influenced the field as well as a number of PhD studies which have set precedents for research in design to date by using the creative potential of designing to generate insights and/or new solutions (Whiteley 2000; Rust and Whiteley 1998, Wood 2004, Pedgley 2007, and Niedderer 2007c).

These studies show two distinct characteristics concerning their aims, which are manifest through the use of practice as a method and/or outcome: one is the aim to find something out that is not yet in existence which is bound to the creative nature of design. The other is the need to access methods that facilitate and integrate the tacit knowledge of design researchers into their research and thus to tap into knowledge that is not otherwise accessible.

One of the first attempts towards a discipline specific approach that recognises the creative nature of design comes from March (1984) who, referring to Peirce's notions of deductive, inductive and abductive (also: productive) reasoning (Hartshorne and Weiss, 1998, vol. 5: §171), proposes that the latter is the most appropriate for design, because abductive reasoning, as "the process of forming an explanatory hypothesis […] is the only logical operation which introduces any new idea;… "(Hartshorne & Weiss, 1998, vol. 5: §171). Presenting the concept of productive reasoning in the context of design methodology, March (1984: 269) argues that this mode of reasoning is most appropriate as framework for design knowledge, because of design being a creative and conjectural process. This concept is important because it provides philosophical foundations for building a discipline specific approach for design research that embraces both its epistemology and methodologies, and that recognises the creative nature of design.

Beyond its discipline-specific characteristics, design is also an extremely broad discipline, which overlaps with many others, such as social sciences or psychology (e.g. user-centered design), engineering, biology and social sciences (environmental design), philosophy (ethical design) and so on. This entails that design research regularly draws on a variety of methods from other disciplines. Hence, design research has to negotiate different methodological positions with its own.

This negotiation has to proceed on two levels, that of method and that of knowledge. With regard to the former, there is Creswell's mixed methods approach (2003: 208), which helps dealing with the juxtaposition of quantitative and qualitative methods as well as with methods that require joining different frameworks of knowledge to accommodate both explicit and tacit knowledge. With regard to the latter, Williams' model of 'Contextualism' (2001: 159-172) offers an approach to mediating different positions of knowledge and reasoning, such as knowledge of external reality and internal reality (Williams 2001: 117ff , 81ff), which drive the different traditions of research.[1] Both models propose a kind of triangulation of data (methods/knowledge) in order to detect faulty reasoning and can be useful for dealing with the interdisciplinary nature of methodologies in design research.

In summary, design research is characterised by its creative and interdisciplinary nature, and its use of discipline specific-research methods from disciplines outside of design such as psychology, anthropology etc. as well as discipline-specific methods genuine to design. The different methodological approaches can be harnessed intentionally through the aim of design research to make a contribution to its own discipline, and practically through a triangulation of methods to accommodate the interdisciplinary nature and the different approaches to knowledge.

[1] Williams (2001: 159-172) proposes an approach, which he calls 'Contextualism' and which assumes that we can rely on our experience of external reality until we have reasons to challenge it (default and challenge requirement). Context-dependent, this allows us to assume certain beliefs as foundational beliefs without the requirement of foundational atomism, but it also releases us from the circularity of Coherentism. These assumed foundational beliefs may be opened to scrutiny if the context changes. William argues that this approach is permissible because of the normativity of knowledge, which is not some a-priori given, but itself a human construct.

3. Methods in Design Research

Due to the creative nature of design, its interdisciplinary scope, and its positioning within research in general, design research can be seen to draw on 3 different categories of methods: generic research methods; discipline specific-research methods from disciplines outside of design such as psychology, etc; and discipline-specific methods genuine to design.

This section discusses the nature and role of these three categories of methods. I first contextualise and discuss the challenges to the proposed approach to derive a framework for analysing and categorising methods in relation to the flow of knowledge. I then distinguish the three proposed categories in more detail including some examples of the changing use of methods within these categories.

3.1 Categorising Methods

Above, I have talked about three different categories of methods, however, more correctly one might say that there is one main category (generic research methods) with two subcategories: design specific methods, and methods from other disciplines . All three categories overlap, but have their distinction in interpretation and application (fig 1).

Categorising methods in this way is not common. Ususally, methods are distinguished by discipline or field, e.g. social sciences, education, psychology etc., and by type of data, e.g. qualitative, quantitative, or mixed methods (e.g. Creswell 2003). The proposed approach will be useful, because it allows to see commonalities between methods and overcome discipline boundaries, and thus to integrate any methods within a design research framework.

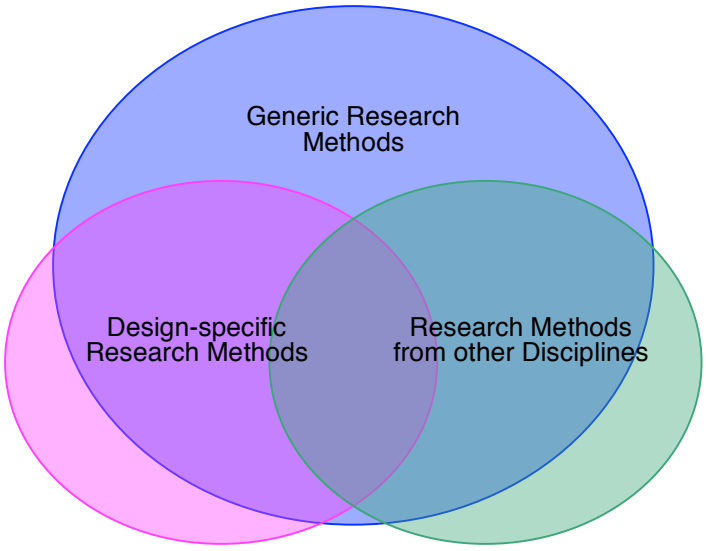

Fig.1: Three types of research methods

A second way of categorising methods is by their role within the research process. Generally, these are data collection and recording, data analysis and interpretation, and evaluation methods (e.g. Robson 1993; Creswell 2003). One may add problem formulation at the start, and methods for communication at the end of the research

cycle. A third way is the distinction by how methods can be employed to manage tacit and explicit knowledge at each stage of research, including research problem, context, methods, and outcomes (Niedderer and Imani 2008).

Each of these distinctions has a different purpose and is useful for sub-categorising different methods. For example, within the proposed distinction, the quantitative/qualitative/mixed-methods approach will be useful in terms of capturing and communicating different kinds of knowledge, e.g. qualitative research is commonly focused on capturing experiential knowledge. I therefore amalgamate them into a generic framework (table 1), which can be used to analyse research methods, their use and relationship in relation to the various factors discussed, and thus to achieve the triangulation of methods under the criteria of rigour discussed in section 2.

3.2 Three different categories of methods

In the following, I discuss the idea of categorising methods into generic, subject specific and design specific research methods. One challenge of this discussion is the methodological implications of different contexts (e.g. different paradigms/contextual models), which change how any method may be applied and results evaluated. For example, textual analysis of a philosophical text may be undertaken with a different aim and result than the textual analysis of questionnaires; and methodologies such as action research, grounded theory, or ethnographic approaches may utilise similar methods but in a different manner and to a different purpose. The discussion of methods is therefore usually conducted within a specific model. Because of the interest in how the application of methods changes within different models, I here proceed by discussing methods by type and across the different categories to allow comparing changes in application. I discuss first the generic (types) of methods, and then some examples of discipline specific methods from design and from non-design disciplines.

3.2.1 Generic Research methods

In this section, I analyse the generic characteristics of different types of methods that appear in research in all fields and disciplines. Most of them vary in their application in different disciplines to an extent that they could be regarded as discipline specific, but the basic idea and role of these methods in the research process is the same. Generic types of research methods comprise for example:

- **Literature search**, which requires searching libraries, (electronic) archives, dictionaries and encyclopaedias etc. by indices or search engines using key words. (Hart 2000). The literature search identifies existing knowledge in the field.
- **Literature review** (Hart 1998), which is mainly based on analysis, including textual or content analysis to ascertain the meaning of a text (Truex 1996), or possibly data analysis. The literature review synthesises existing knowledge and reveals the ‘knowledge gap’.
- **Concept development** is used in theory generating research (Fawcett 1999: 9). It synthesises different concepts into a new one, which in terms of knowledge can be seen as a new (set of) proposition(s) which is subsequently open to theory testing.

Table 1: Framework for analysing the role of methods in research

Methods by				Conceptual framework / paradigm					Knowledge management:	
Stage	Category	Type	Aim / Purpose	Qualitative/quantitative/ mixed methods approach	Criteria of rigour				Explicit knowledge	Tacit knowledge
					Valid/cred	Rel/depend	obj/conf	genral/transf		
Problem formulation / review	generic									
	interdisciplinary									
	design-specific									
Data collection	generic									
	interdisciplinary									
	design-specific									
Data analysis/ Interpretation	generic									
	interdisciplinary									
	design-specific									
Evaluation	generic									
	interdisciplinary									
	design-specific									
Dissemination	generic									
	interdisciplinary									
	design-specific									

- **Theory testing** varies strongly and can be conducted empirically or theoretically, to prove that something is the case or is possible, or that it cannot be. Testing always follows the structure of putting forward a thesis or proposition, and then to conduct some process that generates data that can be used to verify the thesis or to prove it wrong (Fawcett 1999:12). Methods used within this process comprise:
    - **Experiment** is defined by the OED (2009) as "3. An action or operation undertaken in order to discover something unknown, to test a hypothesis, or establish or illustrate some known truth". It is usually seen as conducted under controlled conditions.
    - **Observation**: while data collection methods vary strongly in their application, there are generic understandings of the process of certain methods that warrant attention here. For example, observation can be more or less subjective, but essentially it denotes the process of detailed attention to a pre-selected phenomenon.
    - **Description** is one of the most generic data collection methods. While the perspective applied to any description may vary, the essence of the descriptive method is it to capture and portray a certain phenomenon (usually from observation) as closely as possible through a detailed textual account. (Fawcett 1999: 15)
- **Analysis** is essentially a detailed inspection of data, whether empirical, statistical, or textual, etc. and is defined as

  "1. The resolution or breaking up of anything complex into its various simple elements, the opposite process to synthesis; the exact determination of the elements or components of anything complex (with or without their physical separation)." (OED 2009).
- **Interpretation** is the perspective applied to make sense / extract meaning out of the data at hand through explanation (OED 2009). Interpretation is usually closely associated with and following analysis. Perspectives that guide interpretation may be for example hermeneutics, aesthetics, etc.
- **Comparison** methods also vary strongly. At its core, comparison is

  "**1.** The action, or an act, of comparing, likening, or representing as similar […] **2. a.** Capacity of being likened or compared; relation between things such as admits of their being compared; comparable condition or character. (Always with negative expressed or implied.)" (OED 2009). Comparison is often used as a basis for classification of phenomena.
- **Evaluation: "1.** The action of appraising or valuing (goods, etc.); a calculation or statement of value" (OED 2009). Evaluation methods are used to determine the validity of any data or results gained from any research, to determine the strengths and limitations of the findings presented etc.

Apart from literature search, literature review (and perhaps concept development), which are not essentially effected by any specific conceptual model and research approach, it seems that all other methods are subject to discipline or problem specific modification. In the following, I look at some examples of this modification, before considering what the implications of the need for modification are for using non-design methods within a design research approach.

3.2.2 Discipline specific methods from established disciplines

There are many discipline specific-research methods, and certainly too many to count them all, let alone to talk about them in one paper. I therefore concentrate here on providing two examples of methods that demonstrate how generic methods change when they are adapted to particular disciplines or subjects and their related methodological frameworks.

Example 1: Experiment - observation

Experiments offer a typical example of how methods appear differently in different disciplines. In psychology, for example, an experiment with people might try to eliminate unpredictable elements until one variable is isolated so that it can be tested while the researcher is presumed to observe without personal involvement. In sociology, on the other hand, participation of the researcher may be required to enable him/her to enter the situation they wish to investigate, which may be necessary to observe participants in 'real world situations', and/or to help the researcher develop empathy with participants through immersing themselves in, and gaining experience of a particular situation (Robson 1993).

Example 2: Analysis

There are many variants of analysis methods dependent on the approach, type, and purpose of study they are employed in. There is for example *quantitative-based data analysis* as one might find it in statistics. This kind of analysis usually aims to draw out and interpret numerical data to provide an understanding of the raw data at hand. Statistical data analysis might be used in engineering related design research. When applied within design research, statistical analysis might be used not only to generate specific data, but the study might be designed to deal with the application of the data with regard to design. This will ensure that the results of the study make a contribution to design, and not remain bound to its original discipline. Equally, there are different approaches to *qualitative data analysis*, such as content analysis or discourse analysis. The former is used in social sciences and designed to identify structures or patterns in the text, which are associated with, and classified according to established meanings in order to determine the meaning of a text (Truex 1996). Discourse analysis is more strongly associated with the Humanities and anlyses the meaning of larger chunks of text, taking the context into account (Truex 1996).

3.2.3 Discipline specific methods from design

Discipline-specific research methods for design are as yet not part of the established canon of research methods. First approaches to discuss design research methods have been made by Laurel (2005), by Barrett and Bolt (2007), and more lately by Sullivan (2008). However, the former is mainly a discussion of case studies, the latter two focus on art while the interest here is on design. Durling and Niedderer (2007) have discussed a number of design specific methods and ways of using them. I summarise three of the examples here, although this list is not comprehensive.

1) **"Designing to Test"** is explained as "the making of prototypes… for testing and improvement… of artifacts… One such example is the PhD study by Evans (2002) where the focus of the study was in the development of professional practice, with the aim of evaluating and facilitating the integration of emerging rapid prototyping techniques into the industrial design process. The

intention was to provide guidance to designers on the benefits and disbenefits of rapid prototyping, and the fit of the new technology with designers' traditional ways of working" (Durling and Niedderer 2007: 10).

2) **"Designing as Demonstration":** "…where the researcher has identified a number of features of a product which, if incorporated into a design, would lead to product improvement" (under some previously specified criteria). Here designing has the "purpose of demonstrating that the specification could have practical outcomes." (Durling and Niedderer 2007: 11).

3) **"Designing as Creative Exploration"**: "Designing as creative exploration is perhaps the strongest way of using creative practice within research, and the way that is both most desired and most debated. By designing as creative exploration we mean the working through of a research problem through designing." (Durling and Niedderer 2007: 14). Designing here can be used both analytically to investigate and better understand some concept, and synthetically to generate new insights from combining a number of parameters in a new way.

In the first example, creative practice is used in the way of a testing- experiment. This is similar to traditional methods, but has to proceed through design practice, because the design (guidelines) is (are) conjectural and therefore the reality to be tested has first to be created. In the latter two examples, design is used in a productive way, i.e. in support of an explanatory hypothesis, either in an analytical way or in a synthetic way, which is rather different to established methods from other fields.

3.3 Summary

In summary, this section has discussed three categories of methods, and selected examples of how the different types of methods change within each category and the conceptual approach applied. I have discuss the challenges to the proposed approach, including existing frameworks for categorisation, which have been used to derive further parameters for the proposed framework for analysing methods. In the following section draw the different strands together by explaining how the framework can be used to understand the relationships between methods and knowledge with the view to building design-specific research methodologies.

4. The Methods Map

This final section has two aims: to explain the relationship between methods and knowledge based on the work by Niedderer and Imani (2008), and to provide an example of using methods within the methodological framework. In the previous sections, I have explained the relationship of knowledge, methods and rigour which is important for understanding the relationships between methods as well as the flow of methods to form methodologies. To recap: the aim determines the conceptual model of the research, which is linked to the appropriate model(s) of knowledge. The knowledge model in turn determines the criteria of rigour to be applied for the validation of the research. On a pragmatic level, the aim determines the methods in line with the conceptual model etc. to achieve the desired outcomes and contribution to knowledge. The following illustration visualises this flow (Fig.2).

In order to illustrate the methodological flow, and the role of individual methods within and in relation to knowledge, I provide the analysis of one example in relation to the framework (table1). The example includes an element of design practice to include the creative characteristics of design. The analysis shows how the framework can be useful in the analysis and evaluation of research, and also how the framework can be used to build the methodological structure of a design research study.

The example is a completed research project, which is taken from the author's own work to enable her to know and analyse both explicit and unspoken aspects of the work, which would not otherwise be accessible to the author. While an analysis of external studies might have been of interest to gain insights about the analytical power of the framework, this will need to be part of later research due to the constraints of this paper.

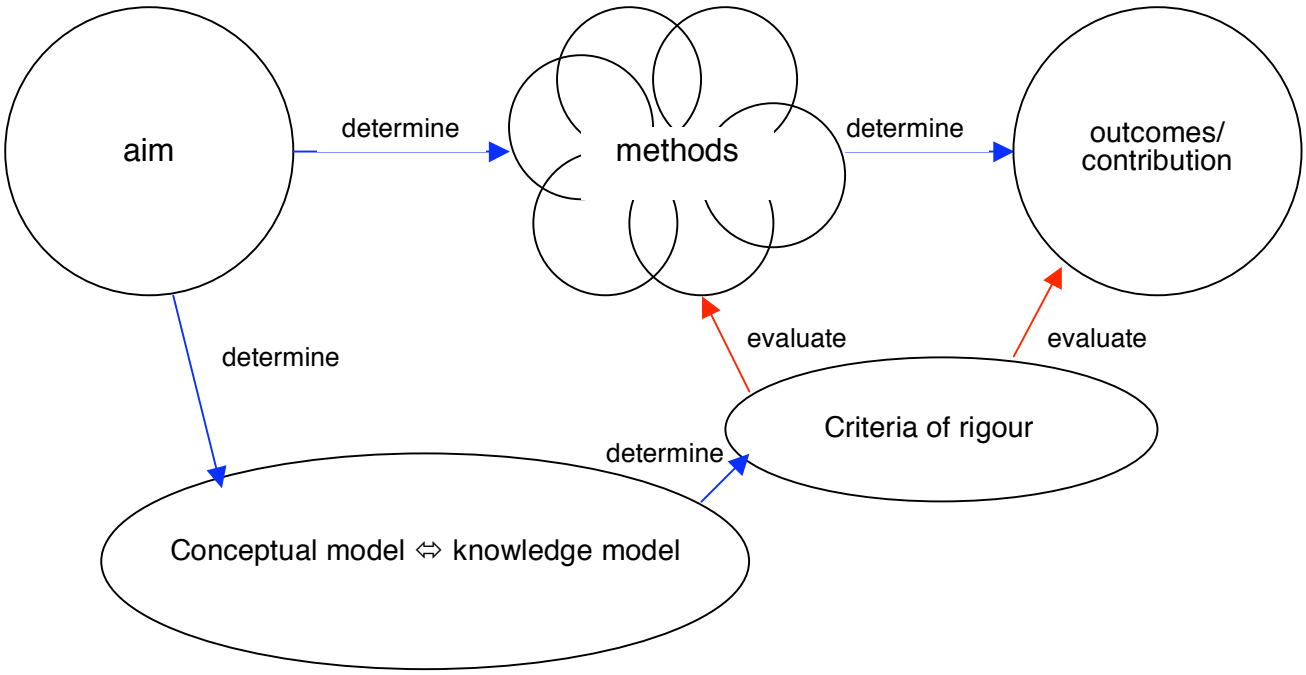

Fig. 2: Methodological relationships within research

Example

The example is taken from a research project completed in 2005 (Niedderer, Harrison, and Johns 2006). The 6 months project set researched the use of Argentium Sterling Silver within design practice.

Background and Rationale:

Argentium Silver (AS) is a new silver alloy, which was developed to overcome certain problems with Standard Sterling Silver (SS) and which has been recognised for a number of advantages. During the development phase, the alloy was mainly tested with regard to quantifiable characteristics such as melting temperature, hardness, etc. using scientific methods. Individual practitioners also used and reported on the alloy, however, not in a systematic and reliable fashion. This project set out to test the performance of AS systematically in the complex context of practice.

The aim of the project was twofold:

- to test the technical performance of the new alloy in the complex context of practice when used with traditional silversmithing methods and new technologies, such as laser welding;
- the research explored the opportunities that might arise for silver design from the use of AS with new technologies, such as laser welding.

The expected outcomes and contribution were:

- a range of silversmithing pieces, made to test the performance of AS using established methods/ new technologies, resulting in knowledge about its technical performance in different situations;
- insights about new design opportunities from the combined use of AS and laser welding.

The conceptual approach of the study and the indicators of rigour

The first part of the inquiry was conducted by comparative testing. This was not based on quantitative testing as was the scientific development of the alloy, but on qualitative evaluation that provided some insight about the qualitative difference in the performance of AS compared to SS. The testing was measured using human perception, and the factor against which results were compared were either a direct comparison of examples, or an evaluation against the previous 15-year experience of the researcher of working with SS, because a single phenomenon cannot be viewed in isolation in a workshop situation. For example, the elasticity of work-hardened AS was tested through comparison with AS. While compared under the same conditions, the results were not measured quantitatively. Instead it was assessed, how it felt when handled, and whether or not the material would break when subjected to further processes required for a particular design.

An example from the second part of the inquiry is the comparison of opportunities available through laser welding as compared to the traditional technique of soldering. Both are joining techniques. Nevertheless there are essential differences. The benefit of laser welding is in minimal heat application, which allows the use of thin, flexible, work-hardened material. In contrast, soldering requires heating the whole piece during fabrication, which softens the silver. Any design using soldering processes therefore has to use sheet material of sufficient thickness to avoid easy indentation within use, commonly ranging between 0.8 - 1.5 mm. This makes silverware expensive and puts a range of constraints on the designing and making of silverware.

The two parts of the inquiry follow different approaches, because they have different aims. The first was to test the performance of the alloy. The second assessed the creative possibilities and potential of the combined use of laser welding with AS for silver design, which was driven by creative inquiry, producing artefacts quasi as a hypothesis. The inquiry can subsequently be justified through theoretical analysis, but in the first instance it is based on creative synthesis and productive reasoning.

In terms of the conceptual approach, the first part is clearly routed in both external and internal realities, which have to be negotiated. This suggests following a critical paradigm. The second part is additionally based on normative judgment because it assesses the possibility of new avenues for silver design. This suggests following a constructivist paradigm to acknowledge a socially constructed reality. Therefore both parts follow the second set of parameters of rigour (credibility, etc.).

The flow of methods and knowledge

Considering the flow of knowledge, both tacit/experiential knowledge and explicit knowledge were brought into the project through various methods. The latter was included through documented scientific information such as metallurgical charts. The former was brought in through the researchers experience of techniques and processes, of interpreting the scientific charts, and of evaluating any results gained through the work. This knowledge was then utilised to conduct the actual research, i.e. the comparative tests and the execution of designs. The research and its result were elicited through descriptive accounts that allowed explicit analysis, interpretation, and evaluation of the findings. Judgments were made against the experience of the expert silversmith, supported by metallurgical information. In this way, the results were evaluated both on an experiential/tacit and an explicit level.

Applying the criteria of rigour

Considering what the criteria of rigour mean in the context of this research, *credibility* and *dependability* refer here to the appropriateness of the methods used and conditions for judgments made. Where creative synthesis is concerned, the reasoning has to be understood not to prove anything, but to demonstrate that something may be, or that it may be useful or beneficial. This may be e.g. new opportunities for production, or for social use, or aesthetic expression. *Confirmability* refers here not necessarily to the possibility of a trial being repeated that is, not everyone would come to the same design if starting from scratch, but that it can be followed and rationalised after the research. On a generic level, *transferability* can pertain to the insight that a new material used with a new technology can offer new design opportunities that can be transferred to searches with other materials and technologies. On a lower level, the findings of how the use of laser welding with thin hard-rolled AS can offer new opportunities for silver design can be applied or transferred to find new designs.

In summary, with the description and analysis of this research project, I have provided an example of how the understanding of knowledge and rigour of research are connected, and how they influence research and its conduct at every stage. A summary is depicted in the framework-table (table2).

5. Conclusion

In summary, this paper has looked at how the flow of methods, and of knowledge are interlinked, and how they can be managed to build rigorous research methodologies that take into account design specific criteria. For this purpose, this research has explained some key concepts such as experiential and tacit knowledge, the contribution to knowledge, and rigour. It has discussed the particular characteristics of design research, creativity and its strongly experiential nature, which have to be taken into account when building design research methodologies. Bringing together a number of different factors in this regard, the paper has developed a framework, which extends the one proposed by Niedderer and Imani (2008) to include the relationship between methods, knowledge, and rigour. The paper has further discussed three different types of methods classified them into three categories: generic research methods, discipline specific-research methods, and discipline-specific methods genuine to design. The analysis of these methods has highlighted their characteristics and roles within the different approaches and stages of research in support of the framework.

Table 2: Applying the framework for analysing the role of methods in research on the example of Argentium Research

Methods by				Conceptual framework / paradigm: **critical/constructive**					Knowledge management:	
Stage	Category	Type	Aim / Purpose	Qualitative/quantitative/ mixed methods approach	Criteria of rigour				Explicit knowledge	Tacit knowledge
					Valid/cred	Reliabil /depend.	obj/conf	genral/ transf		
Problem formulation / review	generic	Comparison & synthesis of data	Find knowledge gap; determine nature of knowledge gap	mixed	Coherence / logic of sythesis/ conclusions	Reliability of sources	Acknowl. role of obj./ subj. data (measure./ experienc)	State limitation of data	Codified knowledge in existing literature	Creative synthesis to identify knowledge gap
	Interdis-ciplinary	Review (analysis of data)	Find existing data in related fields	Quantitative, e.g. data from science discipline	Meticulous review of sources	Reliability of sources	Acknowl. nature of data	n/a	Existing codified knowledge	Comprehension based on prior experience
	design-specific	Review (analysis of data)	Find existing data in design	Qualitative, e.g. observations by practitioners	Meticulous review of sources	Reliability of sources	Acknowl. nature of data	n/a	Personal knowl. made explicit by description	Bring to bare personal knowledge
Data collection	generic	---	---	---	---	---	---	---	---	---
	Interdis-ciplinary	normative (philosophical) framework	For analysis of creative opps.	Qualitative: normative construct	Coher. of reasoning	Within normative constraint	Acknowl. normative foundation	Within norma-tive con-straint	Underlaying assumptions, normative values stated	Use normative values to construct framework
	design-specific	1) test technical performance through test pieces&exampl. 2) explore creative opps. through design examples	1) understand technical perf. of new alloy as a practitioner 2) understand creative opps of combination of AS & laser-weld.	1) Qualitative e.g. systematic obs. of experience by practitioner in action; 2) Qualitative e.g. creative synthesis	1) triangula-tion of ex-periential & scient. data 2) within predeterm. normative framework	1) within determined situation/ conditions 2) logic/ coherence of reasoning	1) confirm within ibid situation 2) confirm based on shared normative values	1) Transf. within ibiid. situation 2)depend on shared values	Bring to bare explicit knowledge which informs personal knowledge in research process	Bring to bare personal knowledge and capability of synthesis (creativity) to conduct research

Data analysis / Interpre-tation	generic	---	---	---	---	---	---	---	---	---
	Interdiscipl.	---	---	---	---	---	---	---	---	---
	design-specific	1) material-experiential analysis of results 2) determine creative advance within set framework	1) understand results from point of view of a practitioner 2) understand creative opps available & their significance	1) Qualitative e.g. systematic obs. of experience by practitioner; 2) Qualitative e.g. creative synthesis & theoret. analysis	1) analysis of exper. Based on practitioner expertise 2) rigorous application of framew.	1) exp. measured against 10 years of expertise 2) logic/ coh. of reasoning	1) confirm. within ibid situation 2) confirm. based on shared normative values	1) Transf. within ibiid. situation 2) conf. depend. onshared values	1) & 2) Use description to make exper. knowledge explicit and available for analysis & evaluation	Use tacit knowledge inherent in professional experience and expertise to make qualitative analysis
Evaluation	generic	---	---	---	---	---	---	---	---	---
	Interdis-ciplinary	1) Comparison of techn. data 2) Comparison of conceptual results	1) Evaluation to verify exp. data 2) Normative evaluation of creative results	1) Mixed: triangu-lation of exper. & scientif. data 2) Qualitative, e.g. comparison with normative framework	1) triang. of experiential & scie. data 2) within predeterm. normative framework	1) evaluat. against 10 years of expertise 2) logic/ coh. of reasoning	1) confirm. within ibid situation 2) confirm.: shared normative values	1) Transf. within ibiid. situation 2) conf.: shared values	1) Compare tacit knowl. (descriptive accounts) and explicit knowl. (data) to verify new knowledge	Make tacit knowledge explicit through description & thus available for evaluation
	design-specific	---	---	---	---	---	---	---	---	---
Dissemi-nation	generic	---	---	---	---	---	---	---	---	---
	Interdis-ciplinary	1) & 2) Written documentation (conference/ journal paper)	1) & 2) Provide explicit analysis to communicate new knowledge	1) mixed; join various data 2) qualitative	n/a	n/a	n/a	n/a	Make res. explicit to open it to scrutiny & to communicate new knowledge explicitly & transferably	Use description to explain and communicate tacit knowledge explicitly
	design-specific	Exhibition	Provide experiential evidence	1) & 2) Qualitative	n/a	n/a	n/a	n/a		Use artifacts to convey exper. underpin results

The outcome of the research has been an overview of the different types of methods, and a framework for mapping the flow of methods and knowledge through the stages of research, the application of which has been illustrated through an example by the author. The contribution of this research consists of an enhanced understanding of what types of methods are available and how they can be used within the flow of research methodology to enable a holistic approach. The will allow researchers to choose more deliberately which methods to use at which stage and for what purpose.

6. References

AHRC (2008) *Research Funding Guide 2007/08*, Arts and Humanities Research Council, Bristol. URL: http://www.ahrc.ac.uk [August 2008]

Aroni R., Goeman D., Stewart K., Sawyer S., Abramson M. & Thein F. (1999) Concepts of Rigour: When Methodological, Clinical and Ethical Issues Intersect. *AQR*, Vol. 2000. URL: http://www.latrobe.edu/www/aqr/offer/papers/RAoni.htm [May 2001].

Barrett, E. and B. Bolt (eds.) (2007). *Practice as Research: Approaches to Doing Creative Arts Inquiry*: I.B.Tauris Publishers.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks: Sage Publications.

Cross, N. (ed.) (1984). *Developments in Design Methodology*. Chichester, NY: John Wiley & Sons.

Cross, N. (2001). Designerly ways of knowing: design discipline versus design science. *Design Issues*, 17 (3): 49.

Cross, N. (2003*). Designerly Ways of Knowing*. Bird.

Curtin University of Technology (2001). *Principles for doctoral coursework programs*. Australia: Curtin University of Technology. URL: http://research.curtin.edu.au/local/docs/graduate/GS-CWDoctorates.pdf [December 2008]

Durling, D. and K. Niedderer. 2007 The Benefits and Limits of Investigative Designing. *IASDR International Conference 2007*. Hong Kong: Hong Kong Polytechnic University.

Durling, D., Friedman, K. & Gutherson, P. (2002). Editorial: debating the practice-based PhD. *International Journal of Design Science and Technology,* 10 (2), 7–18.

Evans, M. A. 2002. *The integration of rapid prototyping within industrial design practice.* (Ph.D thesis, Loughborough University)

Fawcett, J. (1999). *The Relationship of Theory and Research*. Philadelphia: F. A. Davis Company.

Freeman, J. W. and Neely, R. B. (1990). A structured approach to code correspondence analysis. *Proceedings of the Fifth Annual Conference on Computer Assurance* Volume 25-28, 109 – 116.

Gorard, S. (2002). Fostering Scepticism: The Importance of Warranting Claims. *Evaluation and Research in Education,* 16 (3), 136-149.

Grayling, A. C. (2003). Epistemology. In N. Bunnin and E. P. Tsui-James (eds.), *The Blackwell Companion to Philosophy*. **(**37-60). Oxford, UK: Blackwell Publishing.

Hamberg, K., E. Johansson, G. Lindgren, and G. Westman. (1994). Scientific Rigour in Qualitative Research—Examples from a Study of Women's Health in Family Practice. *Family Practice.* 11(2), 176-181.

Hart, Chris. 2000. *Doing a literature search*. A Comprehensive Guide for the Social Sciences. Sage.

Hart, Chris. 1998. *Doing a literature review*. Releasing the social science imagination. London: Sage.

Hartshorne, C. and Weiss, P. (eds.) ([1931–58] 1998). *Collected papers of Charles Sanders Peirce (vol. 5)*. Bristol: Thoemmes Press.

Indiana University Southeast. (2005). *Research Policy Manual*. Indiana, USA: Indiana University Southeast. URL: http://www.ius.edu/acadaffairs/pdf/ResearchPolicyManual.pdf [Dec 2008].

Laurel, B. (ed.) (2003). *Design Research: Methods and Perspectives*. Cambridge: MIT Press.

March, L. (1984). The logic of design. In N. Cross (Ed.) *Developments in design methodology*. Chichester, NY: John Wiley & Sons, 265-276.

Millo, R.A. de, R. J. Lipton and A. J. Perlis. (1979). Social Processes and Proofs of Theorems and Programs. *Communications of the ACM*. 22(5), 271-280. URL: http://www.loai-naamani.com/Academics/Concepts/Social_Processes.pdf

Morse, J.M., Barrett, M., Mayan, M., Olson, K. and Spiers, J. (2002). Verification strategies for establishing reliability and validity in qualitative research. *International Journal of Qualitative Methods*, 1(2), Article 2.

Niedderer, K.(2009). The Culture and Politics of Knowledge in Design Research: How to Develop Discipline Specific Methodologies. In *Design & Cultures. 5th Annual Design Research Conference 2009*. Spokane, WA, USA: Washington State University, Spokane.

Niedderer, K. and Imani, Y. (2008). Developing a Framework for Managing Tacit Knowledge in Research using Knowledge Management Models. In *Undisciplined! Proceedings of the Design Research Society Conference 2008*. Sheffield, UK: Sheffield Hallam University.

Niedderer, K. and S. Roworth-Stokes. (2007). The Role and Use of Creative Practice in Research and its Contribution to Knowledge. *IASDR Conference 2007*. Hong Kong Polytechnic University.

Niedderer, K. (2007a). A Discourse on the Meaning of Knowledge in Art and Design Research. *7th International Conference of the European Academy of Design*. Izmir, Turkey: European Academy of Design.

Niedderer, K. (2007b). Mapping the Meaning of Knowledge in Design Research. *Design Research Quaterly,* 2: 2 (April 2007).

Niedderer, K. (2007c). Designing Mindful Interaction: The Category of the Performative Object. *Design Issues* , 23: 1 (Winter 2007).

Niedderer, K., Harrison, C. & Johns, P. (2006). Exploring the Creative Possibilities of Argentium™ Sterling Silver. *Design Research Society Conference WonderGround*, Lisbon, Portugal: IADE.

OED. (2009). *Oxford English Dictionary*. Online. URL: http://dictionary.oed.com

Pedgley, O. (2007). Capturing and analysing own design activity. *Design Studies*. 28 (5), 463-483.

Polanyi, M. (1967). *Personal Knowledge*. London: Routledge & Kegan Paul.

RAE. (2005). *RAE 2008: Guidance on submissions*. URL: http://www.rae2008.ac.uk [Dec 2008].

Robson, C. (1993). *Real World Research*. Blackwell.

Rust, C. (2004). Design enquiry: tacit knowledge and innovation in science*, Design Issues,* 20(4), 76-85.

Rust, C. and Whiteley, G. (1998). Analogy, complexity and holism - drawing as 3-D modeling. *Art and Design Research Journal,* 6 (Autumn/Winter 1998).

Sullivan, G. (2005) *Art Practice as Research: Inquiry in the Visual Arts*. Sage.

Tobin G.A. and Begley C.M. (2004). Methodological rigour within a qualitative framework. *Journal of Advanced Nursing*, 48(4), 388–396.

Truex, D. P. (1996). *Text-based Analysis: a brief introduction*. Online: http://www.cis.gsu.edu/~dtruex/Presentations/tbintppr.pdf

Williams, M. (2001). *Problems of Knowledge: a critical introduction to epistemology*. Oxford University Press.

Wood, N. (2004). Unknown knowns - knowledge elicitation for multimedia in craft learning. *Challenging Craft Conference*. Gray's School of Art, Aberdeen, UK. URL: http://www.challengingcraft.org/ [11/10/2006]