Reflections on Craft Research *For* and *Through* Design

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ABSTRACT
As design practice has become more integrated in HCI research, there are on-going discussions around the role of design in research. Design research may take different forms, among which 'Research for Design' and 'Research through Design'. While, by definition, these two differ in their focus and result – the first informs the creation of a design artefact and the second aims for a contribution to knowledge – this paper presents a case study of design research in which Research *for* and *through* Design were used iteratively to gain insight into hybrid craft – an integrated physical-digital craft form. Based on our own reflections, this paper discusses what different roles these two strategies may play depending on the research topic under study; the phase in the design process; and the level of abstraction of the research activity and knowledge gained. It thus argues that using Research for and through Design *together* is a powerful strategy.

Author Keywords
Research for Design, Research through Design, design research, craft, hybrid craft.

ACM Classification Keywords
H.5.m Miscellaneous.

INTRODUCTION

In the last decade, the focus of HCI has shifted within the so-called 'third-wave' and use contexts have been broadened from workplaces to homes with the premise that the study of interaction should include elements such as culture, emotion and experience [e.g. 1, 3, 13, 21]. With this shift, and as design practitioners have become more and more integrated in the HCI research community [14], it has become more common to combine design activities and research in so-called 'design research'. After all, the third wave includes a broad range of technological issues and concerns of human experience which can be served with a design perspective [4]. As a term 'design research' does not provide much clarity regarding the topic under study, methodology, and ultimate goal, which is why researchers have attempted to classify different types of design research. Frayling [10], for example, names the strategies *'research into design'* – research that studies the topic of design, e.g. design history, aesthetics, or theoretical perspectives –, *'research through design'* – research that uses design action as a tool or a method, e.g. materials research, (concept) development work, and action research where findings are communicated through a research diary –, and *'research for design'* – research that contributes to the creation of an artefact, which is the final goal. These views are still important to HCI nowadays, and Fallman [6] makes a distinction between 'research-oriented design' – the ultimate goal of which is to create a new artefact –, and 'design-oriented-research' – the ultimate goal of which is to generate knowledge, through the designing of an artefact, specifically the kind of knowledge that would be difficult to gather without the designed artefact. Fallman's 'research-oriented design' is thus similar to Fraylings's 'research for design', while his 'design-oriented research' resembles Frayling's 'research through design'. While we could have adopted either of these two terminologies we will use Frayling's terms for this paper, which we will refer to as RfD (research for design) and RtD (research through design). As the next section will show, each of these research strategies has its own strengths in contributing to research and design knowledge. Although design research practice is often not clear-cut and limited to one proposed strategy, and foci of different approaches may extend beyond those traditionally stated for RfD and RtD, it is important to reflect on the application of these strategies – and the combination thereof – to various research topics and approaches in order to understand how design research practice may best be served by different strategies. To this end, this paper presents a case study of the application of *research for design* and *research through design* strategies to craft research. We reflect on our own practice and discuss what we have learned about the topic of our

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research – hybrid craft, a craft form in which physical and digital materials, tools, and techniques are combined – through these two different strategies. We use our research into craft as an example of a process in which we used both RfD and RtD. We do not claim that craft research is the only or best example to illustrate these approaches but rather that it is a suitable topic – as we will address – among other things because of its combination of known and unknown factors. We saw opportunities within our research to reflect on our design research methodology, and we believe that making such reflections transparent to the community can help other design researchers to select which strategy to use in future studies, by increasing insight into the beneficial features of design research strategies, as well as open up a space for discussion and more case studies around these strategies. This paper now first presents an overview of the roles of research through design and research for design in the next section, after which it addresses our own research topic and activities, along with brief summaries of the types of findings from these research activities. We will end with a discussion around the roles research through design and research for design played in our research, and how we think this may be applicable to design research in general.

RESEARCH *FOR* AND *THROUGH* DESIGN

Within design research and HCI communities there is still plenty of discussion on the role of design in research and HCI. For example, it has been posed that there is a distinction between qualitative design-based and quantitative model-based HCI [18], within which the former seems closely connected to third-wave HCI and the latter to first- and second-wave. Model-based HCI aims to use measurable dimensions to study products, systems, or phenomena, and aims to evaluate designs based on repeatable and generalizable methods. In contrast, design-based HCI argues that nuanced insights into user experience may be lost with the reduction into measurable factors. This strand aims instead to holistically explore users, use contexts, and design solutions, while taking into account human factors such as emotion and engagement. The success of such 'holistic design solutions' is often difficult to assess because attempts to measure or quantify certain elements of the design contradict the tenets of design-based HCI; after all, each user, each design, and each use instance is unique. Similarly, some authors have argued that design, or design research, needs to be formalized as a methodology in order to make contributions on theory, content, or methods [e.g. 9, 36]. However, others [e.g. 8, 14, 32] oppose this view and argue that the nature of design makes it difficult, and in fact counter-productive, to try and formalize a design methodology. Gaver argues that design research tends to be 'provisional, contingent and aspirational' [14, p.938], which makes it unfalsifiable in nature. He offers some explanations on why there are so many different interpretations of what design research is and what it should be, for example because it is a 'pre-paradigmatic' field – a field where no dominant underlying theory or way of working has been established. However, the author's other explanations suggest that the lack of convergence may not be required or desired for the progression of the field; for example, because design research is a generative discipline it is able to create multiple worlds of design that may not overlap or be compatible. Gaver is further quick to point out that perhaps it is not such an undefined field after all; there are plenty of tenets most design researchers agree on, such as: a focus on some variation of user-centered research – keeping the potential target users in mind, and involved, throughout the design process –; the exploration of a large range of design options; attention for detail in the work; and the belief that the practice of making will lead to richer understanding [14]. At the same time, methodologically, design has come to play a more important role in third-wave HCI as designers seek inspiration beyond pure user-research, in more exploratory processes [3], e.g. the use of cultural probes [13].

In the design research community, as opposed to for example in product development companies, most researchers are concerned with gathering knowledge to contribute to existing knowledge of research or practitioner communities, and thus RtD appears to be the dominant form of design research. The use of design action – the development of design concepts and the creation of interactive prototypes – can be beneficial. RtD has been argued to produce several beneficial contributions to HCI, such as the identification of opportunities; the creation of concrete artefacts that embody theory and technical opportunities; and the contribution of holistic research that includes the framing of the problems and the road towards a solution [35]. Furthermore, it allows for design solutions to be evaluated in real-life contexts; for designers to learn about the topic by doing design activities; and for design activities to lead to discussions and new insights and ideas [17]. RfD, on the other hand, typically gathers knowledge for the design of a product or system through methods such as interviews or focus groups and does not include design action in this research process. However, taking a slightly broader interpretation of RfD implies that the result hereof does not need to be a 'final' product. RfD can also inform the design of a new artifact that can subsequently be used in further research through the formulation of design guidelines or knowledge around design context, user group, requirements, etc. In other words, *RfD can be used to inform RtD* (See Figure 1). Similarly, RtD, in addition to providing knowledge on the research topic, can inform design guidelines, design specifications, new ideas, insights into gaps in existing knowledge, *which can inform further RfD* (Figure 1). As Fallman also acknowledges [7], RfD and RtD are thus not two isolated research strategies but can be used together. In our own work, RfD and RtD were used in this way. We will discuss how these strategies complemented each other as our design research knowledge

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into hybrid craft increased. By providing reflections and discussions within a case study, we aim to give more insight into how these strategies may unfold in practice, and offer guidance to design researchers in the selection of appropriate methods for their practices.

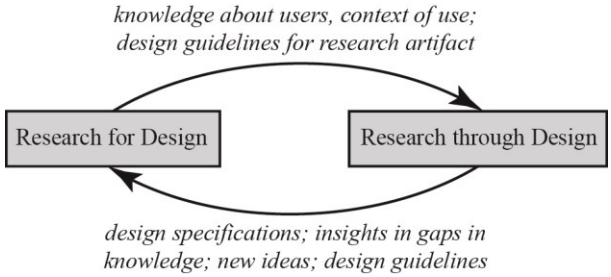

Figure 1. Using RfD and RtD together: findings from the one activity can inform further work in the other.

CASE STUDY: RESEARCH INTO HYBRID CRAFT

Our research focused on developing a notion of a *hybrid craft* practice and formulating design guidelines for the design of products or systems that can facilitate this practice. Based on the premise that people nowadays often engage in making practices in physical realms, e.g. making or adapting toys, clothes, or furniture; and digital realms, e.g. making websites, photo collages, and apps, we developed an interest in the area where these realms come together and craft forms may arise that combine physical and digital craft practices. *Hybrid craft* is thus a process in which *both physical and digital* materials, techniques, and/or tools are used, which results in a creation that consists of both physical and digital elements (where the digital elements are still digital, as opposed to printed, for example). Here digital materials are considered to be digital files such as photos and music, but also text or code; and digital tools to be, for example, software packages required to work with digital materials. An example of hybrid craft could be the creation of a custom interactive product such as a media playback device or photo display, for example by using platforms such as Arduino or Raspberry Pi. We will discuss our own hybrid craft toolkit, Materialise [15], later in this section.

Because the focus of this paper lies on the discussion of RfD and RtD while using craft research to illustrate, a comprehensive review of craft literature lies outside the scope of this paper (see [15] for an overview). It should suffice to explain that in our research we employ a broad definition of craft: it is considered a 'careful form of making', or as Sennett says: 'doing a job well for its own sake' [30, p.9]. While this may seem to imply that one has to be 'skilled' or good at something, this idea is rejected; instead, it is suggested that, in order to be considered craft, a making activity has to be done carefully – with thought, deliberation, and care – and well, within one's own abilities. Craft is thus not limited to traditional disciplines such as woodwork and weaving, but instead can include digital technology in its process, and a craft result may be entirely digital [e.g. 12, 22]. Further, while there are on-going debates around the relationship between craft, design, and art [e.g. 2, 27, 31], it has also been argued that these are three overlapping areas rather than exclusive practices [e.g. 31]. Therefore, our interpretation of craft includes forms of making that may traditionally be classified in either of these domains. Hybrid craft has the potential to be established as a new craft form that fits this broad stance on craft and can take place in our everyday lives as we make things that integrate our physical and digital surroundings.

Design research was considered a particularly apt approach to the research. Craft is typically one of those topics that would benefit from a design-based, holistic, third-wave approach, because it is embedded in social and personal contexts, and it deals with people's personal interests and mental processes; which makes it very difficult to generalize. Further, the large diversity in craft practices – the diverse possibilities of crafting, the different practices people engage in, the different things they make, and the ways they do this – makes it difficult to break these practices up in measurable entities.

Within our research both RfD and RtD strategies were used. Because hybrid craft within our definition is an envisioned future practice that is currently hardly practiced in everyday life, it could not readily be studied through observations or interviews. Therefore, an interview study was carried out to gain insight into existing *physical and digital* craft practices, in order to compare these practices and identify how they may suitably be combined into hybrid practices. Because we ultimately wanted to design a system that could facilitate hybrid craft, and design guidelines, this interview study informed ideation activities, and thus formed the RfD part of our research as it informed the design of this system. In addition, we felt that hybrid craft was typically an area in which it would be difficult to generate knowledge without the use of concrete designs or interactive prototypes; after all, it is often difficult for people to imagine how they would use a new system that is unlike anything they currently have. Therefore we also designed and evaluated the Materialise toolkit for hybrid craft, from which we derived a more thorough and detailed understanding of what forms a hybrid craft practice may take, as well as design guidelines. This thus formed the RtD part of our research. It should hereby be emphasized that as an RtD prototype, the primary goal for Materialise was to increase insight in potential hybrid craft practice and potential tools or toolkits to support this practice, rather than to embody comprehensively our view on what this new craft form ideally should be, e.g. Materialise did not focus on carefully working with materials, or skill development.

Craft has recently become of interest to the HCI and design research community, and new designs have been created that integrate craft with technology or that propose novel forms of technological craft. A comprehensive overview of these existing designs lies beyond the scope of this paper

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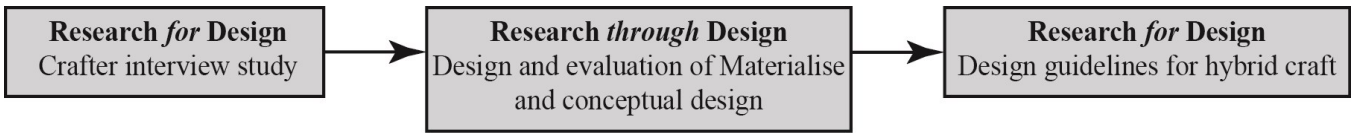

Figure 2. Visualization of our design research process. RfD, the crafter interview study, informed RtD, the design and evaluation of Materialise, which then informed design guidelines for hybrid craft (RfD).

but goals for such designs include: making craft accessible for everyday users [e.g. 24, 29], making more meaningful or personalized objects [e.g. 11, 28], promoting craft activities [e.g. 25], reflecting on craft's role in manufacturing [e.g. 37], supporting education [e.g. 5], exploring input mechanisms [e.g. 26, 34], and making it easier to build prototypes [e.g. 23, 33]. As can be seen from these goals, design research for craft has thus far mostly been instrumental to other goals. As a result, there are no existing reflections on design research methodology for craft research in the literature, e.g. how design practice can be used to inform new craft practices or develop new craft tools. Thus, while the primary goal of this paper is to reflect on RfD and RtD strategies using craft research as an example – and thus aim for knowledge that extends beyond craft research –, it can further aid researchers studying craft specifically in determining what research strategies to use, by providing through its case study an overdue reflection on using a design research methodology in craft research.

Research for Design: Crafter Interview Study

Because hybrid craft practice could not readily be studied – within our specified vision of this practice that uses, for example, digital media files –, it was also difficult to envision what design may be realized that could give insight into hybrid craft practice. Before carrying out RtD it was thus required to carry out RfD to be able to realize a meaningful design artefact. As such, RfD action was done first in the form of interviews with crafters who worked with physical and digital materials. The findings from this study informed the design of a hybrid craft toolkit, Materialise, which was subsequently evaluated in a set of workshops, and developed with conceptual design action. From these design activities, design guidelines for hybrid craft were derived, which can in turn be considered RfD because they can inform the creation of further design artefacts; see Figure 2 for the design research process.

The interview study with physical and digital crafters served to increase insight into craft practice and compare findings around physical and digital practices. Findings were used to explore how these realms may be combined in a hybrid practice. A total of sixteen crafters were interviewed, of whom eight worked with physical materials, and eight worked with digital materials (Table 1). Both professionals and recreational crafters were included to get a wide range of views on craft practice. The following definitions were used: for 'professionals' their craft was their main source of income, or their job; for 'semi-professionals' craft was not their main source of income or job, but they did make a small amount of money from it in one way or another; and finally, 'amateurs' did not make any money from their craft. In line with our interpretation of craft, participants were included who could traditionally be classified as artists, crafters, and designers. Participants were mainly recruited from within the personal and professional networks of the researchers, and engaged in different disciplines to try to uncover a variety of interesting aspects of craft, rather than a comprehensive understanding of a specific craft discipline. Where possible, interviews took place at the location where participants usually crafted. In some cases, mostly for the digital crafters, this was not possible for logistic reasons, or not beneficial because there was no specific location where crafting took place. Participants further actively used examples within the interview to illustrate what they were talking about.

A narrative interview approach was used: participants were encouraged to tell their personal stories around their craft practice, while an interview guide was used loosely to elicit new stories [16]. Topics in this guide included: how the craft was done; how participants started and learned their craft; what materials and tools they used; and why they did it. Other themes were discussed in more detail when

Physical crafters				Digital crafters			
Crafter (pseudonym)	**Craft**	**Pro/semi-pro /amateur**	**Age**	**Crafter (pseudonym)**	**Craft**	**Pro/semi-pro /amateur**	**Age**
Jim	Hairdresser	Professional	38	Marc	Photographer	Semi-professional	43
John	Wood and metal hobbyist	Amateur	54	Tim	CAD modeller & designer	Professional	28
Mary	Glass artist	Semi-professional	56	Emily	Stop-motion moviemaker	Amateur	47
Lucy	Mixed media artist	Amateur	42	Margaret	Blogger	Amateur	54
Vicky	Silk painter	Semi-professional	54	Erik	Electronic music DJ	Semi-professional	34
Carol	Jewellery designer	Amateur	58	Martin	Web developer	Professional	28
Paul	Guitar builder	Semi-professional	68	Ann	Photo collage maker	Amateur	43
Tina	Paint artist	Semi-professional	52	Nick	Software developer	Professional	54

Table 1. Overview of the pseudonyms, craft disciplines, professional statuses, and ages of the interview participants.

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brought up by participants, e.g. their way of working; challenges; risks; and social aspects. Although in some cases observation of crafters may be a more suitable approach, e.g. if one aims to understand or learn a specific craft, we were more interested in crafters' personal motivations and views on their practices, which is why a narrative interview approach was chosen. Interviews were audio recorded, and photos were taken of work, tools, and materials. To analyze the data, first a 'research portrait' was written up about each participant based on the interviews: a written story about the background and craft practice of the crafter [19]. These portraits were used to form a coherent representation of each crafter while including participant quotes (of them talking about their craft) as well as researcher observations (e.g. what the workshops looked like, and mood and expression of the crafters) [16]. Subsequently an 'open coding' approach [20] was used to thematically analyze these portraits, along with the photos, in which related findings were grouped and labelled.

What We Learned From the Interview Study

The interview study addressed multiple angles of craft practice, such as materials, tools, craft processes, craft results, motivations, and social factors. By thematically coding the sixteen research portraits we classified 856 data excerpts into 169 codes and sub-codes. This abstraction process from raw data through research portraits to thematic findings resulted in comprehensive findings around physical and digital craft practices in the form of characteristics of craft in these realms. We further were able to compare the practices in these realms and derive some initial areas of interest for the design of systems for hybrid craft. Because it would be impossible to comprehensively summarize our research findings within this paper, we here highlight a few findings that led to interesting design ideas for hybrid craft. We learned for example that physical and digital craft materials have very different characteristics, e.g. while physical materials are malleable, fathomable, and autonomous – material behavior, and skills and knowledge thereof, determine what a crafter can do with them –, digital materials are reusable, infinite, and more subservient – digital crafters could use and reuse their materials to different ends without similar material constraints. In order to combine physical and digital materials in hybrid craft they need to be brought closer together, for example by implementing tangible interaction mechanisms for working with digital media, making digital media available as physical 'building blocks' so that they can be used alongside physical materials, and implementing more surprising and autonomous behavior for digital materials (a characteristic crafters strongly valued in physical materials). We also saw that digital craft tools were not successful in supporting digital craft: crafters selected and used a limited number of tools – e.g. based on previous knowledge, cost, or availability, of which they had limited knowledge. These tools often dictated what crafters could do within their craft processes and results, instead of allowing them to flexibly select tools 'ad hoc' to suit different needs in different phases of the process. We proposed that digital tools could be more like physical tools: task-specific and limited in number of functions, visually showing their affordances, and capable of being visibly arranged within a workspace. Surprise and discovery were further important in the craft process for both physical and digital crafters – e.g. in materials reacting expectantly or ideas evolving throughout the process, and we expected that by combining the realms more surprising features could be implemented by unexpected interchanges between physical and digital materials. We further found that while physical craft is typically static and cannot be changed anymore by the crafter or someone else, digital craft is always editable and dynamic. Hybrid craft can result in creations that are both static (in maintaining certain physical characteristics) and dynamic (in containing editable digital content). Craft was further often social and crafters enjoyed working together or co-located, as well as sharing their craft results. These insights gave ideas into what we could design for hybrid craft as a research artifact to gain more insight into how this would work in practice.

To further benefit from the interview study, the research portraits about the interview participants were directly used in idea generation activities using a method we have called 'idea generation through portraiture' [16]. Here new ideas were generated by starting from a research portrait about a crafter and thinking about what could be designed for that person if their purely physical (or digital in the case of digital crafters) practice included also digital (or physical in the case of digital crafters) materials, tools, and techniques. By using the output of the interviews direction as input for ideation, we used RfD directly to inform the following RtD activities that will be described next.

Research through Design: Design and Evaluation of a Hybrid Craft Toolkit

Using the 'idea generation through portraiture' method, ideas were generated for a system that could facilitate hybrid craft and that would allow us to learn more about how this practice would take form. The design that was chosen to be developed and prototyped was Materialise, a toolkit for hybrid craft with which physical creations can be built around digital media files [15] (Figure 3). Apart from being directly informed by the research portraits through the employed ideation method, Materialise further implemented some of the themes from the interviews, e.g. exploring how physical and digital materials and tools could be used together in a tangible building process, how the static physical and dynamic digital can be negotiated, and how such a toolkit can be used in a group setting. The conceptual design that was done after the Materialise evaluation further explored themes arising from both interview and prototype evaluation findings.

The Materialise prototype was realized using .NET Gadgeteer [33] and consisted of a large variety of different

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building blocks that could be used to build hybrid creations around digital media. Two 'active building blocks' were implemented that could display a series of digital images – blocks with a screen – and one active building block could play a series of audio files – a block with an attached speaker and audio controls. Other building components included modified Lego blocks – that could now be attached to the other blocks in the set with magnets – wooden blocks in different shapes, rings, a pin board, metal connectors, hooks, clamps, and magnets. This large variety of different blocks was expected to leave plenty of opportunity to build different creations with the inclusion of digital images and audio. In the Materialise design, digital media were readily available as building blocks (this was a proposal from the interview findings) and it was expected that people would iteratively build with different physical and digital materials. Active building blocks were further implemented in such a way that they communicated with each other: if one block (dis)played media for which another block had associated media – set to form a relation by the user using a dedicated software tool – these media would be (dis)played at the same time. This was expected to provide surprising outcomes in the craft process, as well as dynamic functions and interactivity in the craft result (these could still be changed by changing the media).

Figure 3. The Materialise prototype.

We organized a set of four creative workshops in which small groups (3-4 participants per group) of designers, crafters, parents, and teenagers tried out Materialise using their own digital media. Because we learned from the interviews that craft is often social, small groups interacting together with the one-off prototype was expected to be an effective set-up. In the workshops, participants were first given time to explore and get to know the toolkit with a set of example media, after which they were asked to select some of their own digital media, which they had brought into the workshops, and build a hybrid creation around their own media. The four teenage girls, for example, built a physical model of their college which included the active building blocks on which photographs of their classmates were shown (Figure 4). This scene was accompanied by the audio of the song 'I'm not a girl, not yet a woman' by Britney Spears, with which the girls (aged 17-18) indicated to be at a special point in life where they were going from college to university and, apparently, felt like they were between being girls and women.

Figure 4. The teenagers' hybrid representation of their college, including the physical elements: 'the piazza', 'the yellow umbrellas', and 'the trees where the freaks hang out'; and the digital elements: two photos of their classmates, and the Britney Spears song.

What We Learned From Materialise

Letting potential users try out the Materialise toolkit provided various valuable insights into the design and into hybrid craft in general. We thematically analyzed notes on observations during the workshops and group interviews at the end of each workshop. Again we here highlight some findings that serve the goals of this paper while we refer the reader to [15] for more detailed findings of this study. We learned for example that allowing for exploration, experimentation and iterative building across digital and physical crafting was very important because, as was also seen in our interviews with crafters, ideas evolve throughout the process and a toolkit needs to allow for this. Relatedly, digital and physical materials provided different starting points for a creation. Digital media appeared to be concrete and therefore restrictive, e.g. they displayed a specific event or person, while physical materials were much more open for exploration. Physical materials thus gave participants more freedom but also made it more difficult to think of a meaningful integration with digital material. We realized that more flexible means to adapt and find new physical and digital materials would help in this respect. It further became apparent that in the design of Materialise digital and physical making phases were still too separated: selecting, editing, and uploading digital media took place mainly on the computer using the dedicated software tool, after which physical construction took place entirely outside of the computer. We learned that

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physical and digital phases needed to be more integrated, for example by employing tangible interaction mechanisms (Figure 5). Another realization we had was that Materialise formed a 'beginners' kit' for hybrid craft, in which the focus lay on experimentation while the possibilities for building something that can last were limited due to choice of materials and construction. Different designs could therefore be considered for more experienced hybrid crafters who may want to move beyond initial explorations. Such insights were not anticipated beforehand and would have been extremely difficult to gain had we not created Materialise and let people try out our system. Findings from the workshops led to a set of design guidelines for hybrid craft, alongside new conceptual ideas that illustrated these guidelines (see Figure 5 for some example ideas for cropping digital media through tangible interaction). These guidelines and ideas addressed, for example, the availability of digital and physical materials; material behavior; tangible mechanisms for tools, materials and techniques; context of use; finalization of craft results; and hybrid skill development. The RtD strategy within our research thus allowed us to gain valuable insights into our design and hybrid craft practice that were unanticipated following earlier RfD activities.

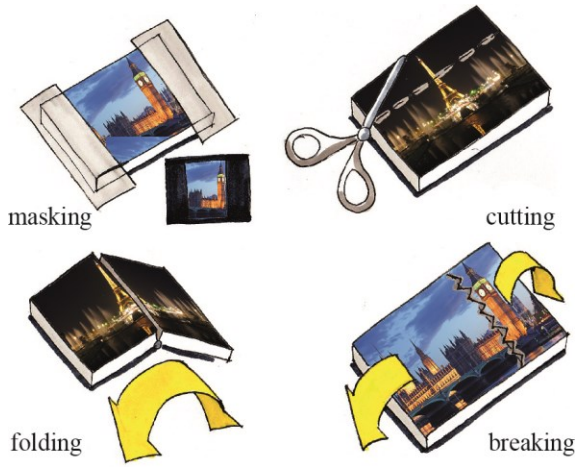

Figure 5. Example ideas for cropping digital media using tangible interaction and dedicated new hybrid craft tools.

DISCUSSION

As we have shown so far, RfD and RtD played different roles in our research and they led to different findings. Because we used RfD and RtD together in our design research we did not focus on the defining difference that the one leads to the design of a product and the other to the generation of knowledge [10]. In our process it was the interchange of both strategies that led to both a designed artifact, and increased knowledge in our research topic and design guidelines. In this discussion we now turn to three other main insights we gained on the roles of RfD and RtD in our design research process, namely: what design research topics they may be used for; the phase in the design research process they are used in; and the level of abstraction of the activity and the knowledge gained. By discussing these insights we aim to contribute to on-going discussions around the roles of design research and to initiate further reflections on the use of RfD and RtD.

Design Research Topics

When we embarked on this design research into hybrid craft we had yet to formulate a clear vision on what hybrid craft is. Because hybrid craft practices within our specified interpretation were not prevalent in everyday life, we could not go out and ask people how they go about doing their hybrid craft. We wanted to design a system that could facilitate hybrid craft but it was difficult to determine what to design because so many factors about hybrid craft were still unknown. We felt we could not start immediately with a RtD approach because it would be unpredictable if our design would be even successful in uncovering relevant information. We thus first had to do research to inform the design that would be the basis of our RtD using a RfD approach. Because there were plenty of existing physical and digital craft practices we could learn from, these lent themselves for our RfD. By first understanding existing physical and digital craft practices we could draw conclusions from a comparison of these practices and anticipate what design features we could implement that may increase our insight in hybrid craft. Thus, we saw that *RfD is a suitable strategy when the topic of research is already happening or existing* (e.g. physical and digital craft). In this case a suitable research plan can be made to uncover those elements of the research topic that may inform the design of the artefact that is the goal of RfD. On the other hand, *RtD is a particularly apt strategy when the topic of research is new, unexplored, and not currently existing* (e.g. hybrid craft). After all, in such approaches it is difficult for users to envision how they may engage in new practices or use new products if they have never encountered something similar before. Be it through a sketch, a scenario, or an interactive prototype, design researchers can embody their visions on new practices in the design of artefacts that can help to communicate these visions to the users.

Phases in the Design Research Process

Related to the previous point, we saw that we could use RfD and RtD in different phases of the design research process. Within the unknown area of research, we felt more comfortable with doing RfD early in the process to gain insights that could inform our RtD later in the process. We thus used RfD and RtD iteratively in phases that informed each other (Figure 2). While we could have designed a system to facilitate hybrid craft at the beginning of the process based on our vision of hybrid craft, it would not have been informed by any, or only theoretical, knowledge of craft practice, and thus it may not have succeeded in uncovering valuable knowledge on a new craft practice. Instead, we opted to *empirically inform our design by*

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employing RfD first. Of course, different strategies are possible and other designers may argue for the creation of design artefacts early in the process and redesign after user feedback in several iterations. There are further different roles for different design artifacts in different phases of the research, e.g. a sketch may trigger more open and conceptual user feedback, while a sophisticated prototype will trigger detailed, technical feedback. Designers can thus consciously choose at what level of detail they want to present their ideas to the users by adapting their medium, and early phase designs may thus be better served with a sketch or a scenario. We acknowledge that embarking on RtD early can be helpful in certain design research processes, for example when there is a clear idea of where design solutions may be sought, but for more complex research areas, empirical research and RfD can be a powerful informant for initial designs.

Level of Abstraction of Activities and Knowledge

We finally saw a difference in the level of abstraction with which we carried out our RfD and RtD activities, and in the knowledge that we gained from these activities (Figure 6). When we say 'concrete' here we refer to 'raw' findings about a specific case, e.g. a person or a prototype, without necessarily being transferrable to other instances. When we say 'abstract' we mean findings that may be based on a specific case but are also applicable to other cases, e.g. the design guidelines formulated based on our findings are abstract while a user's comment on the Materialise prototype is usually more concrete. As a whole, the crafter interviews took place at a high abstraction level. Although our questions were partly concrete (e.g. what materials and tools did crafters use), and partly more abstract (e.g. why did they like it, and if they consider what they did a craft), by going through the interview analysis and looking across participants' stories, we abstracted the findings and derived insights about crafters' practices at a higher level of abstraction. We were able to formulate characteristics of physical and digital craft that looked beyond the concrete details of specific practices, from which insights into hybrid craft could be derived. On the other hand, the design of Materialise, took place at a low level of abstraction. After having formulated an initial vision on hybrid craft we had to make this vision concrete in the design of a system. This system may not completely embody all elements of hybrid craft, but it functioned as a concrete example that could make it clear to users what we envisioned for this practice. Because there was a concrete design present, and it was difficult for users to envision what practices they may engage in far beyond this presented design (as we saw clearly in our workshops), findings from RfD initially remained on a concrete level (e.g. feedback on the working of the prototype, or what they may use this specific design for) and it was up to the design researchers to then abstract these findings into a comprehensive notion of hybrid craft (moving to a higher level of abstraction). Subsequently, design guidelines were derived on a high abstraction level, which formed further RfD that may inform future concrete designs for hybrid craft. Figure 6 visualizes this process. Hybrid craft practice (top centre of the figure) is the new

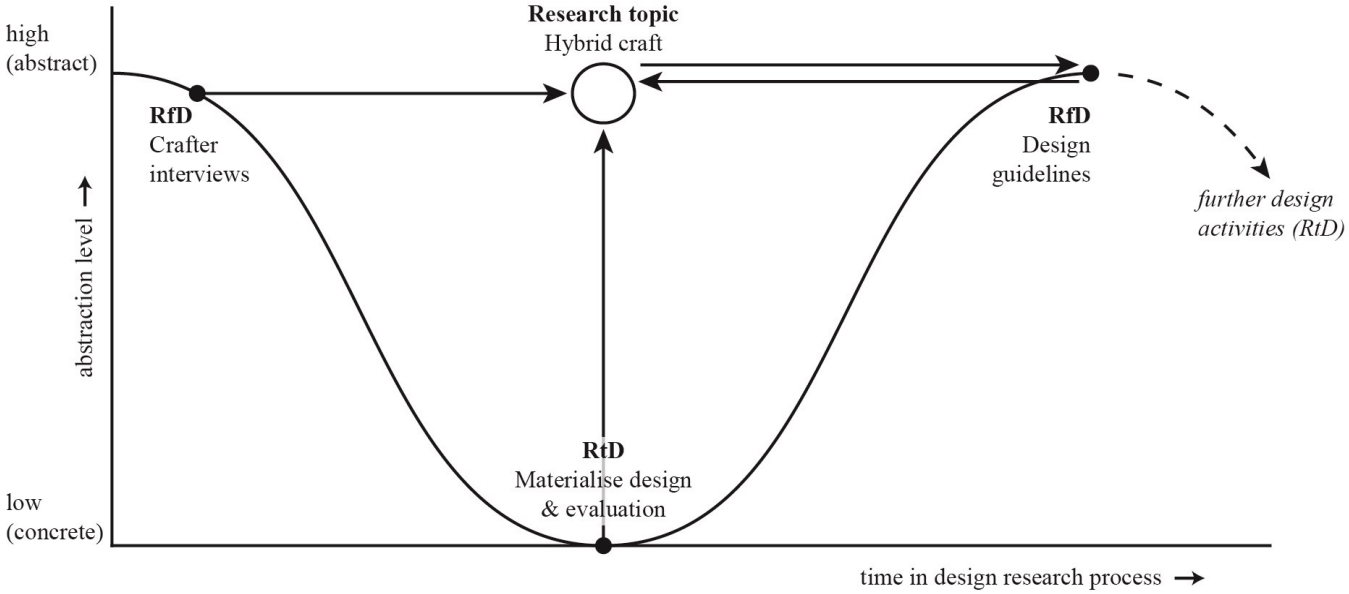

Figure 6. Visualization of the roles RfD and RtD played in our design research process. Both crafter interviews (RfD at an abstract level) and the Materialise design and evaluation (RtD at a concrete level) were used to inform our research topic, hybrid craft (top center), through translations of findings over time and over abstraction level. These activities together led to an understanding of hybrid craft (top center), from which design guidelines were derived (RfD at an abstract level). These design guidelines are both informed by our understanding of hybrid craft, and can increase this understanding, for example through further design activities (further RtD at a concrete level). RfD and RtD thus iteratively inform each other.

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practice in which insight was to be gained on an abstract level. This could not be done directly because users could not be asked directly about this unknown practice. Therefore, a work-around had to be found by informing hybrid craft through different strategies: RfD into other related practices, at a high level of abstraction, that could lead to insight through horizontal (over time) translation of insights; and RtD for hybrid craft, at a low level of abstraction, that could lead to insight through vertical (abstracting) translation of insights. The derived comprehensive notion of hybrid craft led to design guidelines – RfD at a high level of abstraction – which both are informed by the knowledge about hybrid craft, and can further inform hybrid craft through the development of future designs. Note that this figure shows a simplification of reality, i.e. the design research process is usually not a smooth linear process as depicted; there are more factors at play than only time and abstraction level; and research activities, such as the crafter interviews, can occupy multiple abstraction levels. Moreover, the research topic is depicted in the horizontal centre of the figure to indicate that knowledge around this topic is gained throughout the process; it is not completely known from the beginning of the process, and design research typically does not end with knowledge of the topic, but extends to applications of this knowledge, e.g. in design guidelines. The circle representing the research topic is therefore also a simplification of reality in its placement, and is loosely connected to the time axis.

Thus, from Figure 6 we can conclude that *RfD can lead to both concrete and abstract findings*, depending on how it is used in the research (e.g. we could ask concrete or more abstract interview questions), but *RtD cannot directly lead to abstract findings* because there is by definition a concrete design that guides users in their interpretations and feedback, which makes it impossible to reach a high level of abstraction directly; it is the role of the design researcher to afterwards make this translation of RtD to a more abstract level. This difference in the possibilities of RfD and RtD makes it very important for design researchers to consciously choose what strategy to use based on their intended findings; after all, using the 'wrong' strategy may give results that do not reach the desired level of abstraction. Moreover, it makes RfD and RtD particularly powerful when they are used together in a process that includes abstraction and reflection. We have shown how we used these different strategies together in our design research process to gain a comprehensive insight into hybrid craft, and we believe a similar approach can be used for other projects with similar topics that cannot readily be studied through either RfD or RtD by itself.

CONCLUSION

By addressing our RfD and RtD approaches to studying hybrid craft, we have not only presented a case study into the use of these research strategies in craft research, but we have also reflected on our process to provide insight into the unique qualities of RfD and RtD. As we have shown, we believe RfD and RtD are not exclusive practices, but instead, they can be extremely powerful if they are used together effectively and reflectively in a process where one strategy informs the other. We have shown that this is an effective approach for studying topics that are currently non-existing or unexplored because these cannot readily be studied by RfD or RtD by themselves. By consciously reflecting on the design research topic under study; the phase in the design research process in which one wants to gain knowledge; and the level of abstraction of a design research activity and the findings thereof, design researchers can determine their research methodology to include both RfD and RtD strategies accordingly. While we acknowledge that this paper offers only one case study and other cases should be reflected on to support our conclusions, we believe our paper has served to make transparent some of the roles RfD and RtD play in practice, and it has opened up a space for further valuable discussions and case studies into design research strategies.

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