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The generative dance of design inquiry: Exploring Dewey's pragmatism for design research

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In design research, the activities of design and research coalesce. It introduces thorny epistemological challenges and Dewey's pattern of inquiry is explored for its relevance for design research. First, a logical framework for design inquiry is developed that enables to reach warranted conclusions, retrospectively. Second, a temporal framework of activities is inferred, based on the experiences of two PhD candidates.

These frameworks offer guidance to (1) develop transferable knowledge; (2) by oscillating between known theories and uncharted practices until new ideas arise; whereby (3) the value of these ideas is validated through experiments (action validity); and (4) with a community of inquiry (consensual validity). The knowledge produced stems from practice, is tested in practice and serves others in future inquiries.

Keywords: design research, epistemology, design cognition, logic of design, pragmatism

There is an increasing interest in embedding design in research, whereby design is no longer considered an activity separate from research. This is called research through design (Gaver, 2012; Zimmerman et al., 2010), generative research (Sanders & Stappers, 2012), constructive design research (Bang, Krogh, Ludvigsen, & Markussen, 2012; Koskinen et al., 2011) or design research through practice (Dixon, 2019; 2020). These methods have remarkable similarities as each deploys design methods, processes and artefacts as legitimate parts of the research.

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The merger of these two distinct activities — research and design — introduces difficult issues. Design practice and scientific research deploy different methods, live up to different standards (Gaver, 2014; Lindley & Green, 2022) and embrace different kinds of logic (Koskinen et al., 2011: pp.

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15–18). Strongly generalising (Buchanan, 1992; Liedtka & Ogilvie, 2011), research concerns looking back to *understand* the present and design concerns looking forward to *change* the present. Researchers rely on the vast body of theoretical knowledge and justify generated insights by means of methodological rigour. Designers embrace intuition, creativity and experimentation and justify choices made by the success of their artefacts: does it 'work' or not (Gaver, 2014)? If research and design are combined, Gaver argues, the induced theory is 'provisional, aspirational and contingent', which contrasts with theories derived from Popperian falsifiability that aspire to be 'fixed' or concrete (Stolterman, 2008; Lindley & Green, 2022). The epistemological gap underlying the scholarly approaches to the merger of design and research is hardly addressed: in most publications on design research "surprisingly little attention has been paid to the epistemological concerns and general theoretical commitments of such work" (Dixon & French, 2020, p. 4).

Classical pragmatism was developed by William James, Charles Peirce, John Dewey and George Mead and is considered "design's natural epistemology" (Melles, 2008: p. 5). Peirce's abductive reasoning (1877) is considered "the core of design thinking" (Dorst, 2011) and Dewey's logic infused design theory through Schön's *reflection-in-action* (1983), which heavily draws on Dewey's logic (1938). More recently, several scholars unveiled the close relationship between Dewey's pragmatism and design thinking (Dalsgaard, 2014; Rylander et al., 2022), co-design (Steen, 2013) and design research (Dixon, 2019, 2020; Dixon & French, 2020).

In this paper, we explore whether Dewey's inquiry can serve as guidance for design research. We will use the term *design inquiry* for conducting design research in a Deweyan sense, honouring a call of Donald Schön for "new forms of scholarship (..) closer to practice (..) that proceed through a design inquiry, in a Deweyan sense" (Schön, 1995: p. 34). As we will show, Dewey's epistemology offers solid ground for design research, but it does not offer a methodology (Biesta & Burbules, 2003). It can guide co-design processes (Steen, 2013), but in connection with design research it has been proposed as a possibility (Dixon, 2019; 2020) or used to offer retrospective explanations of what has happened (Dixon & French, 2020). We want to know whether Dewey's pattern of inquiry can serve as *guidance* for conducting a design inquiry. To that end, we turn Dewey's inquiry into a framework for design inquiry and – in line with Dewey's ideas – put it to the test, reflect on the outcomes and refine it until we know what to do in order to conduct a design inquiry with justified and transferable outcomes.

The paper is structured as follows. First we discuss the turn to pragmatism in design theory and we develop a logical framework for design inquiry. Next, we describe two designer-researchers who used the framework as

guidance for their PhD projects. We reflect in-depth on the outcomes and develop a framework of activities that may guide future design inquiries.

1 The turn to pragmatism and its methodological challenge for design inquiry

In a design inquiry, research and design activities coalesce. The practitioner of design inquiry is inevitably both a designer and a researcher. This dual role – of a researcher observing an evolving situation and, simultaneously, of a designer who adapts the situation by testing designs – is not common and introduces thorny epistemological issues.

1.1 Dewey's epistemology as a safe haven for design inquiry

Pragmatism offers a way out (Dixon, 2020; Martela, 2015; Melles, 2008) and Dewey's pattern of inquiry is most comprehensive treatise on how knowledge is produced in a pragmatist vein (Talisse, 2002; Martela, 2015), offering the closest thing to an epistemology. It offers a safe haven for designer-researchers, for three reasons.

First, Dewey puts imagination (Steen, 2013) and design at the core of his inquiry for developing new knowledge. In order to understand, we need to explain what knowledge means for Dewey. Dewey no longer considered knowledge to be a distinct and metaphysical entity separate from the world, but discussed it as part of activities and practices. Knowledge, according to Dewey, is *knowing what to do in an evolving situation in order to attain a goal*. For example, we know how to drive a car whilst simultaneously navigating through dense traffic. This knowing cannot be verbalised and can only be learned through practice. Consequently, Dewey refuted the mind/body dualism: knowledge is no longer 'something' in our minds corresponding to the 'real' world, but embedded in activities and practices: "knowing is literally something which we do" (Dewey, 1916: p. 376). Thinking and doing are inseparable.

For Dewey, new knowledge is created in the dynamic interplay of actions and responses: we undergo a situation, act upon it and reflect on outcomes. If we encounter a surprise and no longer know how to act, an inquiry starts (Dewey, 1938: p. 109). We observe the evolving situation and develop alternative pathways of actions and imagine what the impact could be: "an experiment of finding out what possible lines of action are really like (..) in a dramatic rehearsal (in imagination) of various competing lines of action" (Dewey, 1922: p. 190). Subsequently we "purposefully introduce changes which will alter the direction of the course of events" (Dewey, 1929: p. 81) and reflect on outcomes to learn whether we know how to act once again or that progressive inquiry is needed. In other words: in an inquiry we *observe* the situation,

design alternative pathways (note that Dewey never used the word 'design'), *imagine* what the possible outcomes may be and *test* the most promising pathway to reflect on outcomes.

Second, and resulting from the first argument, for Dewey a researcher is not a neutral 'spectator' observing the world 'out there', but someone who is in, engages with and is part of the world (Dewey, 1929). A researcher is an actor who learns from *experiencing* an evolving situation, and *engages* through devising and testing intelligent experiments. Thus, in Dewey's pragmatism "incorporating design into a research project is unproblematic (..) or desirable" (Dixon, 2019: p. 13).

Third, for Dewey theory and logic are instrumental to practice: they are tools to offer plans of action which borrow their meaning and value from their real-world consequences (Hickman, 1998). Conversely, practice is also instrumental to theory so as to continuously develop better tools, knowledge and goals (Hickman, 1998). The implication is that there is no need to prioritise theoretical knowledge over practical know-how or vice versa: it are equal partners.

In short, Dewey considered knowledge to be part of action, and intelligent action to be informed and intentional. That is: knowing what to do in a given situation to achieve a specific goal. Knowledge naturally emerges from our interactions with the world and in order to produce new knowledge, experimentation is essential: "nothing so fatal to science can be imagined as the elimination of experimentation" (Dewey, 1938: p. 434). He paves the way for designer-researchers to conduct design inquiry by actively intervening through designed interventions and artefacts.

1.2 A literature review: Dewey and design research

Melles (2008) was probably the first to discuss pragmatism for design research, explicitly aimed to generate scientific knowledge. He focuses on methodological pluralism and suggests that designer-researchers should use an 'enlarged mixed method' comprising also visual and material means. However, as far as we know his suggestion was not put to the test.

Dalsgaard persuasively demonstrated the high degree of convergence between Dewey's pragmatism and design thinking. He argues that Dewey's pragmatism advances design practice by offering "bridging concepts" (Dalsgaard, 2014, p. 151) to inform situational design challenges with generic theory. Yet, Dalsgaard leaves open the question of how designer-researchers can inform theory through design practice.

Steen framed co-design as a joint Deweyan inquiry: an organising process in which "people jointly explore, discuss, and define a problem and jointly explore, develop, and evaluate possible solutions" (Steen, 2013, p. 20). He explicitly positions communication and joint reflection at the heart of this joint inquiry, highlighting the inherent social nature of knowledge that emerges from the process. A joint inquiry transcends individual, subjective perspectives and offers a pathway to theorise on the basis of empirical outcomes.

Dixon developed an extensive argument to base 'design research involving practice' on Dewey's inquiry, in order to produce insights that a *transferable* to inquiries in other contexts (Dixon, 2020, p. 179). Central to his argument is the view that for design research, new knowledge emerges from action: "ultimately (..) there can be no meaningful understanding of knowledge without taking inquiry into account, and there can be no account of inquiry without reference to action of some sort" (Dixon, 2020, p. 65). In addition to conducting observations and developing ideas, designer-researchers are required to try and test their ideas in the real world (Dixon, 2020, p. 79). This is a messy process, but according to Dixon, Dewey's inquiry offers the logic to structure insights into a valid argument, to theorise and meet academic standards. His "pattern of inquiry weaves together problematic situations, questions, ideas, solutions, experiments to knowledge" (Dixon, 2020, p. 87). In another paper, Dixon and French (2020) reflect on how to do this, yet modestly point out they did so retrospectively, by making sense of what had happened, rather than what was happening.

1.3 The methodological challenge

But although Dewey's inquiry offers a robust logic, it offers only limited guidance for designer-researchers. As Biesta & Burbules (2003) argued, in the context of educational research: "pragmatism offers neither a 'program' (..) nor any specific research methods" (p. 107). Inquiry offers a perspective that changes the relation between theory and practice, but it offers no off-the-shelf *how-to* approach.

Fortunately, Dewey's writings do not leave designer-researchers empty-handed. In Dewey's view new knowledge *emerges* from undergoing a situation, acting upon it and reflecting on outcomes. Those acts are not habitual nor simple trial-and-error experiments: the essence of a Deweyan inquiry is that those interventions are based on intelligent reasoning: they are designed. It is a logic that offers justification of the findings of design research (Dixon, 2020; Dixon & French, 2020). But, as Steen (2013) demonstrated in the context of co-design: it can also offer some guidance how to conduct a joint inquiry. Consequently, we argue that Dewey's pattern of inquiry can serve as an organising principle for design inquiry.

2 Turning Deweys pattern of inquiry into a framework for design inquiry

Dewey touched on inquiry in several of his books, but the most comprehensive discussion of the pattern of inquiry is offered in his *Logic, the theory of inquiry* (1938, pp. 105–122). By turning the pattern of inquiry into *a logical framework* for design inquiry, we hypothesise it will offer guidance for designer-researchers, enabling them to theorise and produce transferable knowledge beyond the scope of their situational design practice.

2.1 What incites a design inquiry?

To start with, we need to be aware of what elicits a Deweyan inquiry. An inquiry does not start with a research question nor with a problem: it is initiated when we no longer understand *the situation* we are in, when we encounter a surprise. To be more precise: when we lack an understanding of the relations between acts and the effects on the evolving situation.

A situation should *not* be interpreted as a single object or event, but as a contextual whole, in which we participate and act (Dewey, 1938: p. 72). We know how to drive a car when we are driving the car. When suddenly the outcomes of our activities can no longer be anticipated, we experience doubt (Peirce, 1877). Dewey argued that doubt is not just an emotion, but part of the situation: "*We* are doubtful because the situation is inherently doubtful" (Dewey, 1938: p. 107, italics in original). When, whilst driving, suddenly a ball bumps on the road before us, we experience doubt. We no longer know what will happen (will a child grab it?) nor what action would be appropriate (brake?). Doubt is part of the situation, including the ball, the speed of driving, the cars behind you and so on, and you no longer know how to act. In short: a design inquiry is initiated with a surprise causing doubt, experienced by a participant who no longer knows how the situation is evolving or how to act in response to it.

2.2 The aim of a design inquiry

Dewey defined inquiry as "*the controlled or directed transformation of an indeterminate situation into one that is as determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole"* (1938: p. 108, entire passage in italics). The aim of inquiry is not merely the discovery of some antecedent facts, but first of all to turn a 'indeterminate situation' causing doubt into a 'determinate situation' in which we know how to act to achieve ends, to develop "a new actionable situation" (Lorino, 2018, p. 103).

Second, the aim is also to *improve* a situation through intentional and well-informed interventions. This sets Dewey's productive pragmatism

(Hickman, 1998) apart from other strands of pragmatism and his 'meliorism' surfaces: "the belief that the world can be made better through human efforts" (Dixon, 2020: p. 145). Inquiry strives for improvement, yet acknowledges that not every problem can be solved and not all unwanted side-effects can be avoided.

Accordingly, the aim of *design inquiry* is to understand a doubtful situation and to improve it by means of design. However, the difference with a conventional design project is that in a design inquiry a designer-researcher strives to transcend the doubtful situation *to generate knowledge that may be transferable to other situations*. That is: to theorise beyond the situation at hand.

2.3 The pattern of Deweyan design inquiry

An inquiry can be summed up as an exploratory approach incited by an unexpected event whereby the problem is provisionally set and proceeds by the formulation and testing of hypotheses through experimentation (Dixon & French, 2020; Hickman, 1997). However, we like to stay close to Dewey's writings. His *Logic* describes the pattern of inquiry as consisting of six stages (Dewey, 1938: pp. 105–122), as depicted in Figure 1.

2.3.1 Determination of a doubtful situation

A surprise causes doubt and confronts us with an indeterminate situation as we no longer know what to do. The situation requires judgement to decide if an inquiry is needed: is it problematic or not? For design inquiry, surprising

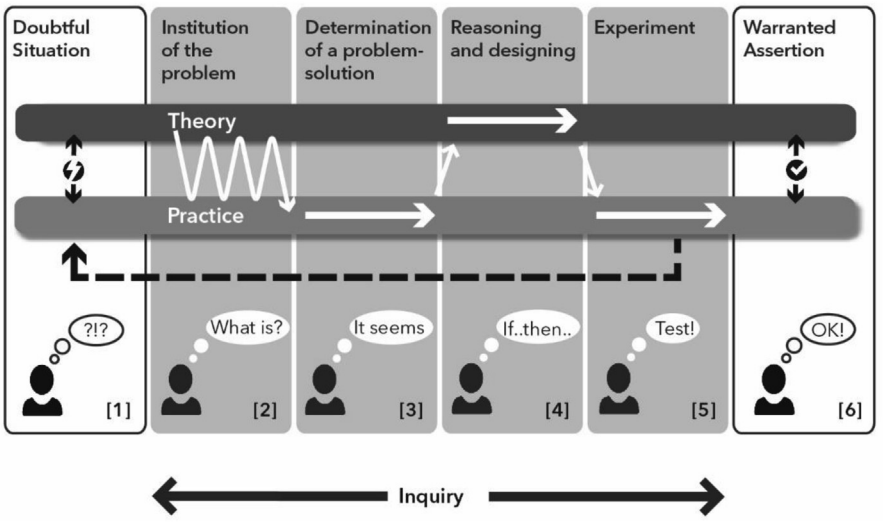

Figure 1 An overview of a Deweyan inquiry. Theory and practice are mutually constitutive, and during an inquiry the focus of the researcher alternates between theoretical development and practical activities. An inquiry is always initiated by a doubtful situation arising in practice and is also resolved in practice through informed experimentation

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events that initiate an inquiry can be a problem experienced in practice, but also an opportunity that suddenly appears.

2.3.2 Institution of the problem

First, an inquirer *provisionally* sets the problem by observing the situation as "without a problem, there is a blind groping in the dark" (Dewey, 1938: p. 112). The problem is temporarily defined (Dixon & French, 2020) and "can later be restated and refined in an iterative process" (Steen, 2013: p. 22). Lorino (2018: pp. 106–107) argues that for Dewey this stage is less about defining the problem and more about 'intellectualising' the situation. The goal is to come to an understanding of the situation, its constituents and their interrelations: what factors are contributory and why? What are causes, what are effects? What is problematic, for whom and why? What are means, what are ends? To theorise beyond the situation at hand, 'intellectualising' the problem is important and goes beyond conventional problem setting in design.

2.3.3 Determination of problem-solution

This stage concerns the process of coming to an understanding of the problem and a possible solution. For Dewey, stating problems without reference to possible solutions is meaningless (Dewey, 1938: p. 112), so understanding a problem is not sufficient to end an inquiry: an inquiry must offer actionable ideas for solutions. During the inquiry, solutions are suggested in the form of ideas marking possibilities to pursue. As such, problems and solutions *co-emerge* (Dewey, 1938, pp. 112–114). Inquirers only genuinely understand a problems once they know what solution is effective: "problem and solution stand out completely at the same time" (Dewey, 1933: p. 201). This co-emergence is remarkably similar to the *co-evolution* of problem (-space) and solution (-space) in design practice (Dorst & Cross, 2001).

2.3.4 Reasoning

This stage concerns the development of a set of propositions of 'facts' and 'ideas' that offer an intelligent interpretation of the doubtful situation and possible solutions on *what to do*. For Dewey, reasoning is developing a *set of propositions* by formulating and reformulating them again and again until a meaningful and coherent whole emerges.

Facts are 'existential', that is: based on observations (Dewey, 1938: p. 113). They reveal relevant factors that constitute the doubtful situation and are selected to offer guidance. Ideas are 'ideational', that is based on suggestions that "flash upon us" (Dewey, 1938, p. 114) while we inquire. Ideas concern possible lines of action: "ideas are statements not of what is or what has been but of acts to be performed" (Dewey, 1929: p. 112). These ideas are operational, formulated as hypotheses in an 'if-then' format to guide subsequent experiments (Dewey, 1938: p. 423): *if* we do X, *then* we expect Y to happen.

Reasoning includes conducting many thought experiments in order to extrapolate the effects of *possible* lines of action, until the most promising one is established.

Designers similarly construct a set of actionable *design propositions* through design artefacts such as sketches, models and prototypes. Design 'reasoning' is the process of iteratively developing parts of the design, putting them together and redesigning them until a meaningful and coherent whole emerges. These artefacts are speculative as they hypothesise about potential implications (Halse & Boffi, 2016), embodying an implicit set of if-then propositions: *if* design X is implemented, *then* we expect Y will happen.

The question is in what form do proposition in a design inquiry need to be: a set of propositions embodied by means of textual hypotheses or by means of design artefacts? Following an argument of Koskinen et al. (2011, p. 6) for 'constructive research', we take the view that design inquiry concerns both imagining new ideas by means of design artefacts and developing an textual argument that supports the design and includes explicit actionable if-then hypotheses.

2.3.5 Experiment

For Dewey only informed experiments will validate if-then propositions. As Biesta & Burbules, (2003, p. 46) argued, only "overt action" can determine the value of both the analysis and the designed intervention. This is not different for designers, as Gaver et al. argued (2001): the accountability of design is that it has to work. Therefore, *only* design artefacts that 'work' – that is: meet anticipated outcomes of the if-then proposition – justify the reasoning done before. The implication is that for design inquiry, the validity arises from conducting and reflecting on the outcomes of experiments, what we call action validity.

2.3.6 Warranted assertion

An inquiry (more or less) ends if the outcomes of experiments are in line with anticipated effects, demonstrating that the inquirer understands the situation and knows how to act to achieve ends. In Dewey's words: the situation is "determinately unified" (Dewey, 1938: p. 121). Dewey defies claims of 'absolute truth', as even the most certain theoretical concepts eventually need elaboration (principle of fallibility), and thus progressive inquiry will refine the knowledge. Instead, Dewey prefers *warranted assertibility* (Dewey, 1938: p. 16): justified, defensible claims that concern the 'best available' knowledge on how to act.

The question is what quality standard are applicable for design inquiry? Prochner and Godin (2021) examined what standards apply to research

through design. They concluded that for designer-researchers working within a pragmatist paradigm, five standards apply to the quality of the research:

- *Transparency*: the research should be presented in such a way that others can follow critically how the conclusions of a particular inquiry have been reached.
- *Contextualisation*: as an inquiry deals with a specific situation, results should be based on contextual evidence.
- *Transferability*: derived insights should to some extent be transferable to other contexts, without expecting that results can be reproduced. Thus, results are evaluated for their applicability by others in other situations.
- *Impact:* the essence of pragmatism is that theory is instrumental to practice. Insights are evaluated for the extent to which their practical implications improve the situation at hand.
- *Sound research methods:* pragmatism lacks methods, yet researchers should proceed according to accepted scientific norms.

3 Two practice-led experiments

Our main hypothesis, formulated as a Deweyan idea, is that *if* designer-researchers use the logical framework for design inquiry, *then* they can generate transferable knowledge beyond the scope of the situation they engage with. As no inquiry can end without experimentation, we put the developed framework to the test by means of two PhD studies.

Both inquirers started their research intuitively; while working in their respective practices they experienced a feeling of doubt that urged an inquiry. And once the design inquiries ended, both projects contributed to their respective bodies of knowledge. Table 1 provides an overview of the main characterisations of the two PhD projects and presents a brief exposition of the two inquiries.

3.1 Facilitating team cognition

The first study started with the feeling doubt of an experienced product designer (first author) who worked in large product development teams on complex high-tech products. In product development it is common to outsource activities to companies with the relevant expertise. Effectively, the teams developing complex high-tech products are composed of hundreds of experts who are located at different sites, belong to different organisations, speak different languages and have different cultural and professional backgrounds. Despite the undisputed advantages of outsourcing, it seemed that the distributed teams needed much time for small adaptations, that response to inevitable set-backs was sluggish and that even the most promising opportunities that surfaced were dismissed. The teams seemed to have lost their

Table 1 Overview of conducted experiments

Case 1: Facilitating team cognition in new product development (2006–2012)	*Case 2: Towards controlled innovation of complex objects (2011–2016)*
PhD Dissertation Facilitating team cognition: how designers mirror what NPD teams do (Stompff, 2012).	Towards controlled innovation of complex objects. A sociotechnical approach to describing ship design (van Bruinessen, 2016)
Topic and institution of the problem Product development of high-tech product requires large multidisciplinary teams that are often distributed spatially. These teams seem less innovative and adaptive to change. Team cognitive properties underlying the alignment and coordination of activities is hindered.	Ship design advances on the basis of small incremental improvements. The lack of a framework for innovation in complex systems such as (offshore) vessels undermines the industry's ability to develop innovative vessels for future needs.
Key Findings (1) Complex boundaries in teams are managed through (verbal) negotiations. There is no joint practice and team members are unable to establish meaningful relations between their activities and those of others. (2) *If* a joint practice is constructed across boundaries, *then* team members can interrelate their activities (3) Designerly representations such as sketches, models or interface designs serve as boundary objects that represent the intended product the team is developing, improving team design processes.	(1) In successful ship design, the design of the whole (the vessel) and that and of its constituent systems co-evolve. Cohesion of these two levels of decomposition is key to develop innovative, complex systems. (2) *If* the focus of designers in ship design is on both levels simultaneously, taking into account the interactions between them and allowing weak system boundaries, *then* innovative ship designs can be developed successfully. (3) A deeper understanding of the social dimension of innovation is required to advance our understanding of controlled innovation of complex systems.
Why a Design Inquiry based on Dewey's pattern of inquiry? The PhD candidate, a professional product designer in product development teams, started with participatory ethnographic research. However, only through conducting intelligent interventions did the problem/solution become known. Dewey's logic offered the foundation for this research whereby design and experimentation were central to improve practice and advance the body of knowledge.	The PhD candidate, a professional naval architect and researcher, first took an outside-in perspective on his practice. Although this helped to refine the research question, it did not provide the insights to advance the practice of designing complex vessels. Dewey's pattern of inquiry, including experimentation, led to justified theoretical insights that improved practice.

responsiveness to change, unintelligently sticking to plans and planning no matter what happened.

The designer-researcher wanted to improve the situation and conducted several, seemingly incoherent inquiries simultaneously. One was focused on understanding how teams align and coordinate their activities intelligently, called 'team cognition', to enhance collaboration in distributed teams. The other was focused on understanding the contribution of user-centred design within those teams, to better understand what designers (such as the designer-researcher himself) can do to improve the situation.

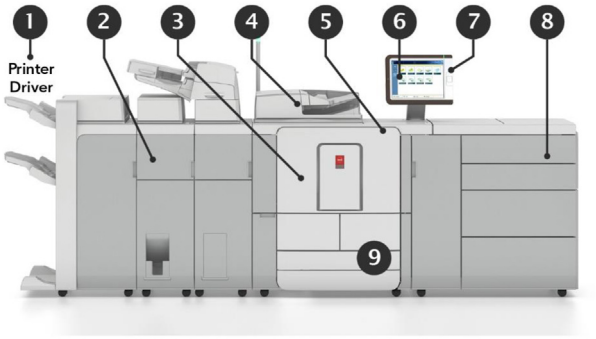

Figure 2 The new product development of this copier/printer provided the context for the design inquiry. Whereby acquired insights served to improve alignment and coordination of activities. The team was extremely distributed: the numbers correspond to distinctive modules that were (co-)developed by different groups that belonged to three organizations and were located on 7 geographical sites spanning the world

It was found that innovative teams jointly construct a practice that enables them to intelligently align activities through jointly constructed prototypes, CAD models, and so on. Individual team members see and become aware of the activities of others and interrelate their own contributions to those of others intelligently through these artefacts. Distributed teams lack this joint practice and rely too much on textual and verbal communication. However, most of these elements of joint practice represent the state of affairs of a project, but not the intended outcome. Artefacts of user-centred design, such as sketches, models or user interfaces represented the intended outcome well. It was hypothesised that *if* representations of the intended outcome are shared, *then* they offer guidance to team members in distributed teams.

In the last part of the design inquiry (experiment), dedicated representations of the intended outcome were redrafted and shared over and over again whilst the project progressed, improving the collaboration considerably. The product developed is depicted in Fig. 2, a professional copier/printer. However, it was noted that the 'fidelity', the degree to which a representation corresponds to the eventual real world, strongly shapes subsequent activities (Stompff & Smulders, 2015), requiring progressive inquiry.

3.2 Towards controlled innovation of complex objects

The second study explored ship design, which is a fairly traditional field. The inquirer (second author) was employed by a company as a naval architect and as a researcher to improve design processes and tools. When discussing the design process with other professionals, he noticed that they almost always talked about prior projects to explain choices made in current projects. To design a vessel, they more or less start with an existing design and adapt it to meet requirements. Since ship design advances on the basis of small incremental improvements, innovation is rare. In order to enhance the

innovativeness of naval design, the inquirer started a PhD project on the innovation of complex objects.

He compared the scientific background of design methodology of ship design with that of other fields. He drifted between theory and practice as the requirements of industry and academia pushed and pulled between relevance and rigour; between practical application and abstract theoretical description. In the first year, the research questions were continuously updated and guiding hypotheses could not be defined.

After a year the designer-researcher reviewed the research in the light of a Deweyan design inquiry. Applying the Deweyan design inquiry provided guidance, a 'method to the madness' of working as a designer-researcher, enabling him to accept the uncertainty encountered in practice and theory. More importantly, it facilitated co-creation of new theory with other professionals and scholars, in parallel with analysing the early stages of design processes of more innovative ship designs. Subsequently, he applied the theory to two projects, while at the same time observing a similar design process at another, related company. An innovative ship design resulting from the inquiry is shown in Fig. 3. These tests provided insights which refined theory, but also resulted in questions for progressive inquiry, concerning the social dimension of innovation processes.

4 *Reflections*

The experiments yielded four key insights on design inquiry, discussed below.

4.1 *Practice-led research*

The first insight is that design inquiry is radically practice-led. Both design inquiries started in practice as the two authors were working as professionals and experienced doubt. Despite their years of experience they had to acknowledge they were facing an issue they did not understand and their working methods no longer seemed effective. A review of the available literature yielded

Figure 3 An outcome of the design inquiry: an advanced subsea rock installation vessel. New insights on enhancing innovativeness of complex objects were put to practice during the initial design stages

unsatisfactory answers and hardly touched upon the challenges confronting them, let alone offered guidance on what to do. There was something hidden in their practices that was problematic, yet unknown. To advance theory and practice, they started a PhD project and became designer-researchers.

Both inquiries also ended in practice, by conducting experiments that met anticipated outcomes: their newly developed ideas seemed to 'work'. These ideas were not just the result of observing and interpreting the evolving situation, but rather of (ongoing) reasoning, designing and experimentation. The interventions eventually mitigated problems in their respective practices and validated their developed theories.

However, the character of the experiments in the two cases varied. In case 1 the experiments were conducted *as part of* the daily activities of the designer-researcher: he continually adapted his activities on the basis of insights gained, and reflected on outcomes. In case 2 the designer-researcher conducted two dedicated experiments, *in addition to* the regular activities, to 'pilot' a new way of working and compare it with conventional working methods. In both cases, the assumptions underlying the experiments were validated in practice.

4.2 Transferability: two principles

The second insight that emerged concerns the transferability of findings. The aim of conducting a design inquiry is not only to improve a situation, but also to develop theoretical insights that transcend the specific situation. In both cases, the developed theoretical insights proved to advance the body of knowledge in their respective fields, as demonstrated by several peer-reviewed publications.

However, meeting conventional scientific standards proved to be difficult. The aforementioned discussion on scientific standards for design research in a pragmatist vein (Prochner & Godin, 2021) was published years after the two design inquiries ended. Thus, both designer-researchers had to meet more conventional standards – which was hard. The biggest issue was that the designer-researchers were no 'objective' spectators, but engaged participants who deliberately intervened, changing the course of events in order to learn. The accepted papers addressed only parts of the inquiries, describing the more 'objective' parts of the inquiries that used widely accepted methodologies, such as conducting interviews, ethnography and video analysis.

Yet, in hindsight we can claim that the five standards described by Prochner and Godin (2021) were met. Both design inquiries (1) had an *impact* on their mutual practices, and the peer-reviewed publications demonstrate that (2) the designer-researchers used *sound scientific methods* that (3) were described in

transparent and (4) *contextualised* way in order (5) to produce *transferable* insights.

This last standard, transferability, is the most difficult one to live up to. How to develop warranted claims with predictive powers that are transferable to other contexts? On the basis of our experiences, we argue that this claim of transferability can be met through action- and consensual validity.

4.2.1 Action validity

Experimentation is central in a design inquiry, whereby experiments are guided by intelligent hypotheses. In both design inquiries, the designer-researchers inferred *actionable* hypotheses from practice, and transformed them into designed interventions performed in the real-world context of their practices. After several iterations, the outcomes were in line with anticipated effects, justifying the underlying theory they developed. The doubt that gave rise to the inquiries – a problematic *indeterminate situation* in which nobody knew how to act – was transformed into a *determined situation* in which the designer-researchers knew how to act in order to improve the situation. The acquired new knowledge was developed, tested and refined in practice and validated through experimentation. We call this action validity.

Without claiming 'truth', we argue that part of this knowledge is *transferable* if described in such a way that others can judge whether it is applicable to their context, in their own design inquiries. That demands to 'intellectualise' (Lorino, 2018) the situation at hand, describing not just the problem at hand, but also relevant constituents of the situation and their interrelations in a transparent and contextualized manner. For example, the theories developed in case 1 concern complex boundaries in distributed teams, and the nature of these boundaries and how they are spanned through design-artefacts are described in-depth, which enables others to judge whether these insights are applicable for their situations.

4.2.2 Community of inquiry (consensual validity)

To reduce the inherent subjectivity, both designer-researchers organised what Peirce named a *community of inquiry* (Lorino, 2018: pp. 158–186): a group of inquirers that offer different perspectives and together build a plausible and coherent account that explains the situation at hand. These inquirers, including scholars and other professionals, deepened the analysis and offered relevant bodies of knowledge. For example, in case 1, all data was closely examined and discussed with three professionals working in the same context and with four researchers. Besides, preliminary findings were presented for feedback to the teams the designer-researcher participated in (Fig. 4). Collectively they unveiled what was hidden in practices and reflected on the outcomes of experiments.

Figure 4 On the left, the community of inquiry (case 1) is analysing findings. In addition to the designer-researcher, four scholars and three seasoned practitioners contributed at several moments in time. On the right, intermediate results are presented for feedback to the team the designer-practitioner participated in whilst conducing his design inquiry

Practitioners cannot know what knowledge embedded in their practices may advance theory, just as scholars cannot know what theoretical concepts may progress practice. Establishing a community of inquiry of practitioners and scholars is acknowledging that knowledge is socially constructed and embedded in practices, and that any claim of objectivity is futile. Instead, the aim is to create warranted assertions that are inter-subjective, constructed by a community of inquirers with the shared goal to advance theory and practice, synthesizing new theories drawing from multiple bodies of knowledge. We call this consensual validity.

4.3 Justification in hindsight

The logical framework (Figure 1) can be interpreted as step-by-step approach whereby the problem is instituted and gives rise to ideas that result in experiments that validate insights. The designer-researchers learned that this logical framework can only be imposed *retrospectively*.

Although both inquiries emerged from doubt as a result of an surprise, it proved to be merely a first stepping stone. Additional observations and outcomes of experiments yielded further surprises and made it necessary to reject hypotheses multiple times. Consequently, the research questions were reformulated over and over again, requiring multiple 'restarts' of the design inquiry. Only after several iterations did activities and experiments begin to make sense, and slowly an understanding emerged that both explained the problem and hinted at possible pathways for resolution.

'Restarts' suggests failure, yet restart is an inevitable part of design inquiry. Whilst progressing, new facts are discovered through additional observations and conducting experiments. New ideas that shed another light suddenly flash upon the designer-researchers. These new facts and ideas require additional literature review and collecting more data – which, in turn, will result in

new and/or adapted hypotheses that need to be validated through experimentation, and so on. Only once experiments yield expected results can a situation be said to be understood, that is: determinate.

Consequently, and somewhat paradoxically, problem setting and research questions that guide an inquiry become known through inquiring. The ongoing reformulation of the problem is a key driver of the inquiry. As Philippe Lorino argued (2018: pp. 105–109): a researcher is "in search of a problem", giving inquiry "its distinct exploratory character". By oscillating between theory and practice, new theories naturally emerge, theories that are justified, but can only be described logically *a posteriori*. This recalls an argument presented by Dixon and French (2020): when following Deweyan logic designer-researchers can only present an argument and evidence once an adequate solution is found: "(i)n this way and only in this way, do we act logically" (pp. 19–20).

4.4 The conceptual leap

In order to deal with the doubt and the lack of ground that both designer-researchers experienced, they had to resort to what is called abductive reasoning. Abduction is a term coined by Peirce (1903) and developed by Roozenburg (1993) for the context of design. It concerns inferring the best possible explanation for a doubtful situation. Abductive reasoning is a creative process that requires an "imaginative conceptual leap" (Martela, 2015: p. 548) in order to "put together what we had never before dreamed of putting together" (Peirce, 1903: p. 227). The designer-researchers used abduction to decide what theoretical concepts may apply to the situation at hand, often comparing several. Eventually they developed new theories and imagine what these might result in. It requires creative reasoning and a leap of faith to decide what new theory might applicable, before initiating time-consuming and sometimes costly experiments.

Although Dewey's inquiry hinges on creativity and imagination (Rylander, 2012, pp. 25–26; Steen, 2013), it "is not a subject that Dewey dealt with head-on" (Dixon, 2020: p. 100). However, in his discussion on intuition (1934) he does offer a useful clue: intuition is "the meeting of the old and the new (..) a quick and unexpected harmony which in its bright abruptness is like a flash of revelation; although in fact it is prepared by a long and slow incubation" (Dixon, 2020, p. 277). It characterises well what both designer-researchers experienced: only after considerable time and many experiments did ideas emerge that fundamentally changed their understanding of the situation and resulted in new knowledge. Design inquiry requires time and effort – in other words: experience – before new intelligent theories 'flash' upon us.

4.5 The pitfall: stalling experiments

In the first stages of the design inquiry (Figure 1), the problem is *provisionally* set in order to guide progressive inquiry. However, the question is what 'provisional' means. Both designer-researchers reviewed literature, made observations, held interviews and wrote preliminary papers to set the problem. In doing so they followed conventional research approaches and used standards applicable to those methods, spending much time establishing a concise problem setting together with their communities of inquiry. They implicitly stalled the more creative and explorative steps of the design inquiry, only to discover that the problem setting had to be adjusted considerably when experiments yielded surprising observations.

In hindsight it became clear that the large amount of time spent on problem setting is a pitfall in which designer-researchers return unwittingly to an overly rationalist problem-solving approach whereby problems need to be understood *before* possible solutions are devised (Stompff & Smulders, 2021). The design inquiry diagram in Figure 1 concerns the *logical* order of reasoning and less the *temporal* order of activities.

5 The generative dance of design inquiry

For Dewey, "isolating elements of an inquiry (..) is one of the main mistakes of rationalist thinking" (Lorino, 2018: p. 108), which results in the aforementioned pitfall. Problem definitions, hypotheses, solutions and standards are interdependent and interconnected, linked by mutual references. The designer-researchers experienced that all elements – problems, hypotheses, solutions, ends – transform all at one time when a break-through idea 'flashed' upon them. Only once experiments based on those break-through ideas yield anticipated outcomes, the situation and its constitutive elements are determined. Consequently, a design inquiry is a creative and explorative process, requiring many iterations and an adaptive mindset. The logical ordering of Figure 1 suggests a step-by-step approach that belies the iterative nature of design inquiry, and we believe an additional framework of activities will offer better guidance to future designer-researchers.

Figure 5 shows a *temporal order of activities*, based on the extensive experiences of the designer-researchers. It highlights design inquiry's explorative nature requiring several iterations before a problematic, doubtful situation is sufficiently understood, supported by outcomes of experiments. Through these iterations relevant constituents and the relations among them become known.

The iterative process is initiated with a surprise that causes doubt and the following activities are done:

- *Provisionally set the problem*: In the course of events a surprise is encountered which results in a doubtful, indeterminate situation. Literature is reviewed, experts consulted but no satisfactory explanations are found. A community of inquiry is initiated to assess the situation from different perspectives and the problem is set provisionally.
- *Making sense*: Constructing a plausible narrative with the community of inquiry that offers an explanation of the existing situation, its constituents and their causal relations. The key question is: what do *we* think the situation is? Data collection and analysis help to disclose the *facts* (relevant constituents of the situation and relations) and give birth to preliminary *ideas* (possible actions) to guide progressive steps.
- *Reason and design*: Developing a promising plan of action, reviewed by community of inquiry that may turn the existing situation into a more preferred one. The key question is: what do *we* think that is best to do? Several ideas are developed into design concept, supported by actionable hypotheses, formulated in an if-then format. In thought experiments possible effects are imagined, often requiring additional sensemaking.
- *Experiment*: Facts and ideas can be validated by putting them to the test in a real-world context and reflecting on the outcomes within the community of inquiry. This activity concerns conceiving and performing intelligent experiments. Often outcomes do not meet expectations, in which case another sensemaking step is required.
- *Justify*: If experiments deliver anticipated outcomes, the situation is determined. An argument needs to be developed that theorises findings and justifies the choices made, following Dewey's logic (Figure 1), and is transferable for future inquiries in other situations conducted by other inquirers.

The iterative order of activities (Fig. 5) will offer guidance to designer-researchers to help them conduct practice-led research that improves situations and practices and thereby contribute to the body of knowledge. Thereby theory and practice are mutually constitutive, each inspiring the other. Design inquiry resembles a dance of equal partners, each responding to subtle changes in the music and the moves of the other, to create something new and beautiful. A generative dance of known theories and uncharted practices, of research and design and of practitioners and scholars when they engage in a community of inquiry − a dance of different disciplines (Troxler, 2022).

We do not claim that the knowledge produced through design inquiry is 'truth': each design inquiry is conducted in a specific context, by a subjective researcher with a small community of inquiry. Still this knowledge can be transferable. To explain, we need to consider what 'knowledge' is for pragmatists. They no longer considered knowledge to be separate from the world or a representation of the world. Instead, they regarded knowledge as *knowing what to do* in a given situation in order to obtain a goal. Rorty, a neo-

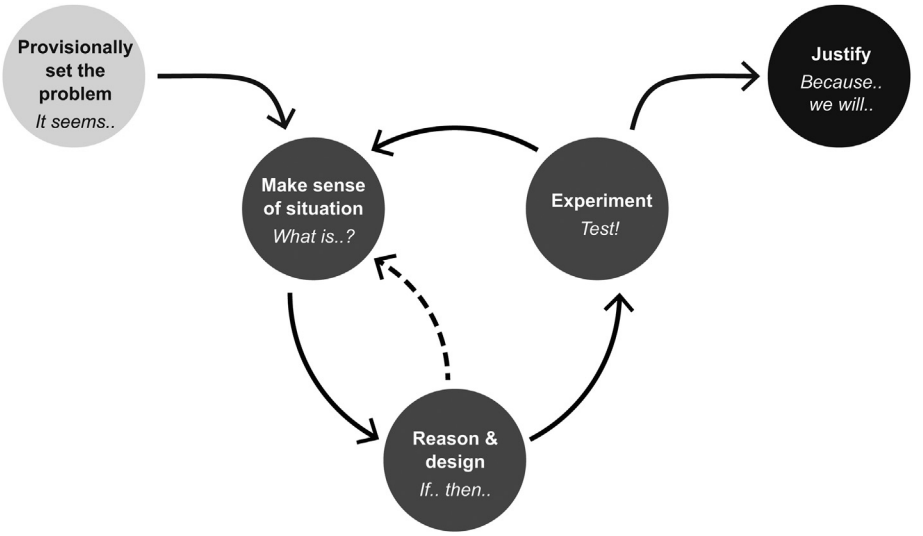

Figure 5 A temporal framework of activities to conduct a design inquiry. It is initiated by an unexpected event causing doubt, requiring that the problem be set provisionally. Then an iterative process of sensemaking, reasoning/designing and experimenting begins, which continues until newly developed hypotheses yield anticipated outcomes

pragmatist, summarised it succinctly: we should not "view knowledge a matter of getting reality right, but as a matter of acquiring habits of action for coping with reality" (Rorty, 1991: p. 1).

The knowledge produced by means of a design inquiry should be viewed as a tool and instrument for predicting the outcomes of our actions to help us understand and improve the situation we are in. Thus the knowledge produced by a design inquiry – developed and tested in a specific practice – should be evaluated for its use to serve future design inquiries, as actionable theoretical concepts that other inquirers can use in their practices. Concepts that always can be challenged, improved or even refuted. Not claiming truth, yet arguing that the newly developed theory is transferable as claims are tested and perfected in practice. It is potentially the most important contribution of pragmatism: to accept fallibility and at the same time reject scepticism (Putnam, 2001).

6 *Implications and limitations*

Both designer-researchers started their inquiry based on the logical framework, taking Dewey's writings as a starting point. They inferred the temporal framework of activities, but whether the combined frameworks can serve as a springboard for other designer-researchers is part of ongoing research. For those interested in practicing design inquiry, note that it is radically practice-led: it is prompted by a doubtful situation in practice and it ends by

testing hypotheses in the same practice. This has three implications for future designer-researchers.

First, design inquiries can be initiated only by someone who is embedded in practice: most often a professional (a practitioner) or otherwise a scholar who actively engages for a prolonged period in a way that is comparable to action research. Second, an inquiry is prompted by doubt, but what is 'doubtful' for one may be perfectly clear for another. Seasoned professionals have met many more situations than novices and have a vast repertoire of action routines. Similarly, senior researchers are acquainted with more theories and methods than junior researchers. Consequently, we believe that matured expertise is highly relevant for design inquiry: if an expert experiences doubt, chances are arguably greater that the situation may provide insights which help to expand, improve or even challenge the body of knowledge.

Third, to advance theory and practice the composition of the community of inquiry is crucial. Seasoned professionals need to bring in expertise, routines, tools and knowledge of comparable situations. Scholars need to bring in relevant bodies of knowledge, to unveil what is hidden in practices through critical examination, and to deploy logical reasoning that warrants justified and transferable claims. An inquiry is not only a generative dance of theoretical knowledge and practical wisdom; it is also a dance of scholars and professionals in a community of inquiry. Inquiry, in a Deweyan sense, is a decisively social endeavor.

7 Conclusions

Last decade a renaissance of pragmatism can be observed in design sciences. This paper explored Dewey's pattern of inquiry as a framework for design research, called design inquiry. First, staying close to Dewey's original writings, a *logical framework* was developed for making warranted assertions in hindsight. Subsequently, a *temporal framework of activities* was inferred on the basis of extensive experiences of two designer-researchers. Distinct activities – sensemaking, designing and experimenting – alternate until a doubtful situation is adequately understood. These frameworks may offer future designer-researchers guidance in conducting design inquiry.

Although design inquiry is decidedly practice-led, it well bridges the practice-theory divide. Theory informs practice by offering concepts that may shed a new light or encourage intelligent experimentation. Practice inspires theory to improve or induce theoretical concepts that offer better pathways of actions. Rigour is obtained by putting experimentation central and organizing a critical community of inquiry that helps to develop transferrable knowledge. However, the knowledge produced should not be conceived of as 'truth'. Instead, it should be considered a tool for action: emerging from practices

and feeding back into practices, to support future inquirers to deal with other doubtful, problematic situations.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests. Corresponding author was affiliated with company described in case study 1 until 2019 Co-author was affiliated with company described in case 2 until 2020.

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