Design Expertise

A Structured Literature Review

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DESIGN EXPERTISE: A STRUCTURED LITERATURE REVIEW

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ABSTRACT

Today research has come far in explaining distinct aspects of design expertise at different skill levels. However, with the increasing number of studies, we argue there is a need to assimilate present knowledge. In this paper we advance the field of design expertise by conducting a structured literature review. Through a systematic search of papers, from 1970 to today, we identify 110 papers concerning design expertise. We then analyze the accumulated research, and map how design expertise research has evolved, in terms of what we know and what remains unexplored. Through the review, we contribute with a distinction of skills acquisition at increasing levels of design expertise.

Keywords: Design expertise, Design theory, Design methodology, Design education

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1 INTRODUCTION

Currently, there is a plethora of different directions in the field of design expertise research e.g., industrial design (Huang and Li, 2015; Oygür and Ülkebas, 2021; Yilmaz and Daly, 2016; Jagtap, 2018; Rusten and Bryson, 2007), engineering design (Ahmed, 2007; Atman et. al., 2007; Steele, 2012), and architectural design (Alipour, 2021; Bernal, 2016; Gulari, 2015; Oluwatayo et. al., 2017), service design (Kuosa and Westerlund, 2012; Wetter-Edman and Malmberg, 2016), software design (Popovic and Kraal, 2010; Petre, 2009), interaction design (Begnum et. al., 2019; Gray et. al., 2014; Lotz et. al., 2015), interior design (Smith, 2015), fashion design (Lee, 2012; Stacey et. al., 2002), web design (Chevalier and Ivory, 2003), and graphic design (Ellmers and Foley, 2020; McLaughlin, 2012). This cluster of diverse, contemporary research contributions strongly suggests that "the need for a new study is not as great as the need for the assimilation of already existing studies" (Light and Pillemer, 1984, p. 169). Based on this observation we argue that a holistic approach is needed to assimilate a scholarly body of literature. Our suggestion is to adopt a structured literature review (the SLR-method as described by Massaro et. al., 2016), to provide new insight to the topic of design expertise and to support future theory building across engaged disciplines. With this paper, we respond to recent calls in research, we aim to accumulate findings from prior research (Tan, 2021), and contribute to the work of renowned design scholars as Cross, Lawson, Dorst and Buchanan, that calls for more research on design expertise.

1.1 Design expertise

In the Cambridge Handbook of expertise and expert performance, design expertise is presented as being ‘the result of a dedicated application to a chosen field’ (Cross, 2018, p. 428; Ericsson et. al., 2018). Like expertise in other domains, expertise in design accumulates over time and is a long-term process (Lawson and Dorst, 2013; Cross, 2006), as "a product of grit, practise, and reflections" (Chase and Simon, 1973; Erisson, Krampe, and Tesch-Römer, 1993). Expertise is more than experience or the possession of talent (Laursen and Barros, 2022). “Acquiring design expertise is influenced by a complex array of factors” which includes skill acquisition, learning declarative knowledge and developing relevant experiences (Lawson and Dorst, 2013, p. 98–99). Prior literature on design expertise typical describes several skill levels, see for example the foundational work on skill acquisition by Dreyfus and Dreyfus (1980) model, and later, in design by Lawson and Dorst (2013) and Dorst (2011). In expertise studies we also find applications of Schön´s model of reflective practice (Schön, 1983) and, the Ericsson model of deliberate practice (Ericsson et. al., 1993; Ericsson and Smith, 1991). In these models’ ideas of different level of expertise have been discussed and positioned depending on how skills are acquired. Present expertise research mostly builds on well-known expertise models (Tan, 2021). Recently a model has been proposed by Mosely et. al., (2018) in which principles of design thinking (Laursen and Tollestrup, 2017) has been applied to the research on expertise acquisition.

Table 1: different levels of expertise correspond to our analytical framework.

Design Thinking Types	Description	Design Expertise Level	Description	Corresponding Levels of Expertise
Result-Focused Convention-Based	Following “the rules of the game”, concentration on design conventions; customs and habits; the set ways of working within a field. E.g. Concentrating on the user and designing from their perspective	Naive Novice	Choosing from a set of prescribed solutions and rules driven. Understands that design problems are individual and situated, and reacts to them. Possess design language acquisition.	Design students
Situation-Based Strategy-Based	Understanding the design situation or context and creating a response specific for that particular setting. E.g. Identifying the “core problem” of the problem situation	Advanced beginner Competent	Able to steer the development of the design problem. Sees the bigger picture. Can tolerate ambiguity and can actively steer the development of the design problem.	Practitioners in Design
Experience-based		Expert	Has an implicit recognition of situations and a fluent, intuitive response.	Expert designers
Developing new schema Redefining the field	Designing the process itself and creating a design situation for themselves. A developed way of working that is imposed upon the problem. E.g. Reframing the design problem to develop something new	Master Visionary	Practice a level of innovation and pushes the boundaries of the field. Work is explicitly aimed at redefining the design field.	

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Table 1 (an extension of the table by Mosely et. al.) shows how novices normally evolve from working with a rule/convention-based way of design thinking to a more situation-based/strategy-based type, and finally, to working innovatively with developing new schema as an expert. To clarify and display a clear foundation in earlier findings, we build on these in our literature review, mapping studies according to level. However, we are also simplifying the seven levels into three (*students, practitioners, experts*), which we are in fact able to divide earlier studies from. Through this SLR study we *seek to answer the following research questions:* RQ 1. How has design expertise developed overtime? RQ 2. What is the focus of design expertise literature and how has it evolved?

2 METHOD

Structured literature review is an explicit method following specific steps (Massaro et. al., 2016. P. 771). Where this study is focused on covering a less explored territory within design research, the general application of SLR studies has been in the context of more widely described research fields such as Accounting (Guthrie et. al.,2012) and Knowledge Management (Massaro et. al., 2015). However, SLRs are not exclusively meant for researching fields with a large body of scholarly contributions but supports the process of covering any scholarly body of literature on the parameters of width (exhaustive data search and collection) and depth (assessment criteria through validity construct) (Massaro et. al., 2016).

2.1 Data collection and processing

Through several search-rounds with different combinations of search-metrics were explored to generate a versatile and representative dataset. Some of the initial data searches revealed 100.000+ hits which needed a large reduction. The search terms were clustered into groups according to which combinations generated the same hits. After investigating the results exhaustively, (check title - check abstract - yes/no) we used the local AUB Primo engine as a directory for papers that were not available through Google Scholar.

Table 2: Research protocol and validity construct of collected data (filtration process guide)

A. Parameters	B. Specifications/variables		
Search engines	• **Google Scholar (w. support by)** • **Primo Search Engine Hub, Aalborg University Library (AUB).** AUB Primo is a database-hub that grants access to sites like Routledge/Taylor and Francis, Elsevier, Science Direct, Springer, Wiley, etc. Provides an elaborate advanced-search function as a supplement to Google Scholar.		
Data sources: (Types)	• **Journals** • **Books** • **Conference papers** • **Dissertation**		
Timeframe of search	• 1970 - 2021 (October)		
	Root/Constant[1] (A)	**Root/Constant (B)**	**Additions to A & B***
Keywords and combinations in search	**Design** Designs Designer Designerly Designing	**Expertise** Expert Experts Experience Experienced Professional Master Practitioner(s)	**Novice** Novices Naïve (Advanced) Beginner Undergraduate Student(s) Non-designer **(Design) Education**
Priority Assessments (for final acceptance and NVivo software import)	**1st priority assessment:** **Keywords** need to be present in headline, abstract or keywords. Preferably present in more than one of the above mentioned. **2nd priority assessment:** **Journals[2]** and their **rankings[3]**	**3rd priority assessment:** **References** to citation classics/main contributors of design expertise: (Lawson, Cross, Dorst and/or Dreyfus & Dreyfus, Schön) **4th priority assessment:** Minimum of one **Citation** Pr. Year (CPY).	**- Papers accepted to NVivo if:** ***Min. 3 out of 4 criteria is met***

*Additions can be placed before, after, or in between A and B.

[1] The rule of the Root/Constant: The Root/Constant must be present in every combination of search-keywords to ensure output relevance e.g., if *design* is not defined along with *expertise or, novice, student etc.*, the metrics will most likely prioritize general studies of expertise - as described in Ericsson et. al. (1993, 2018).
[2] Prioritizing the highest rated *Design research Journals* (we chose Mansfield, 2016, p. 907.)
[3] Journal Rankings (if available) at www.scimagojr.com.

We then read abstracts in the "yes" pile and appointed them to themes. We then narrowed down the themes by collapsing similar themes into one. The resulting piles then went through checks with the

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protocol according to which criteria were met. This gathering and filtering process resulted in a total of 110 papers, which was then imported to the qualitative data analysis software (QDAS) NVivo 12 for further analysis. An example: Design studies articles will go through many rounds IF the criteria of roots are present in title - keyword or abstract. Dissertations and books will be coded in software for references and number of keywords in text.

2.2 Analytical framework and coding

Then we developed an analytical framework a collection of topics ("nodes") which the data was analysed and coded under (in NVivo). Guided by the analytical framework, the next step where to visualize the data and run different data queries in the program. In the following chapter, we present the initial results generated from our dataset and discuss insights, implications, and future research paths from here.

3 INSIGHTS AND RESULTS

3.1 Domains

Through our coding we find, studies of design expertise are de-centralized and scattered between multiple domains. The main contributors are three domains, including: Architecture, Design and Planning; Product Engineering/ Industrial Design and Design Research, Innovation and Technology. Whereas most other domains, only contribute with a few papers each. When coding the domain, we based it on the domain, the institute, which first author was affiliated to.

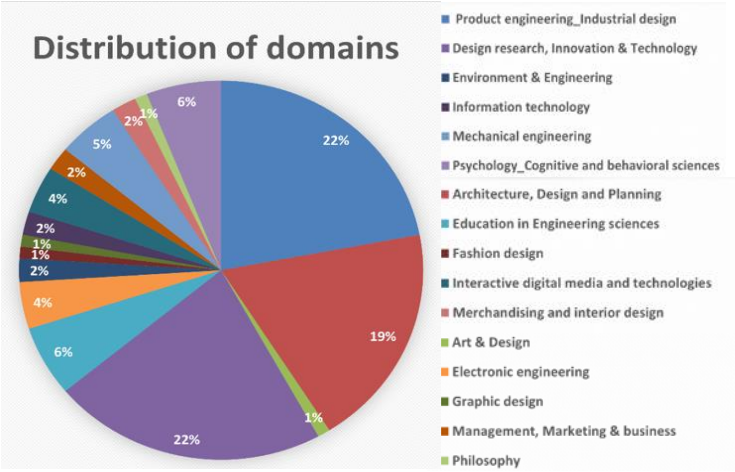

Figure 1: Distribution of domains contributing to the field of design expertise.

This indicates that the field has expanded in multiple directions of the design disciplines, which creates a somewhat scattered image of the field of design expertise. The main contributors each represent a specific domain in which they have conducted research on DE, (Lawson, Architectural Design/Cross, Engineering Design/Dorst, Industrial Design) from these main domains, the branches reach areas like digitalization, interactive digital media, and information technology, where DE is related to system design, graphic design, and interaction design/HCI design. Other areas relate to areas like fashion design & interior design, which is an extension of the industrial design practices with a specialized commercial emphasis. In the field of engineering, we find areas like electronic engineering, software engineering, environmental planning & structures in engineering. Within architecture several areas intersect depending on whether the perspectives are macro (buildings and structures) or micro-oriented (products, systems, or services).

3.2 Methods

Next, analysing the distribution of applied methods in the studies of DE (fig. 2) there is a clear dominance of protocol studies. While protocol studies are highly appraised within design research (Cross, 2001), a few studies critique this tendency, arguing that the artificially created environment in which the participants conduct the design tasks, is not inducing spontaneous or realistic design situation- or setting (Kim, 2019, p. 10; Crilly, 2015, p. 55).

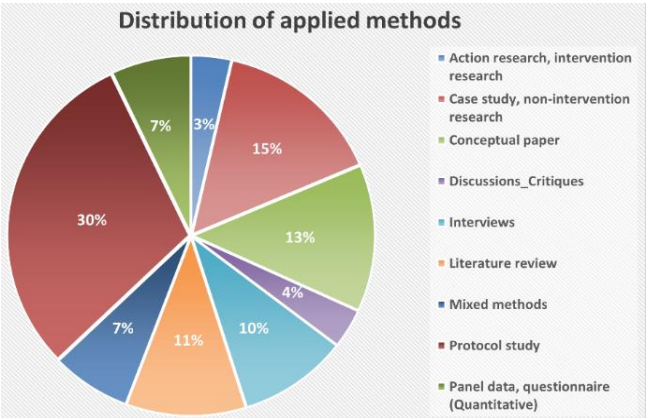

Figure 2: Distribution of applied methods DE.

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The second most applied method is conceptual papers such as (Cross, 1982, 1985, 2006; |Lawson 2005, 2013; Dorst and Reymen, 2004). Looking at Discussions and critiques, we see 4% of the papers collected in this category.

In terms of the thematic evolution of the design thinking field, the themes emerged from the content of the data and were then clustered into three overall themes: Design cognition, Design education and Design processes and practices. The chart (figure 3) illustrates the evolution and distribution of the overall themes Design cognition, Design processes/practices and Design education, as the dominant themes across time.

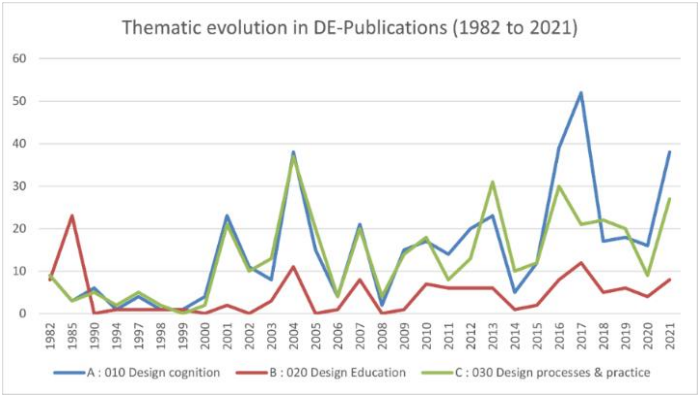

Figure 3: Evolution and distribution of themes in design expertise literature.

As figure 3 shows, from 1982 up to 2000 the papers tend to focus on design education and less so on process/practice and cognition. Post year 2000 and to year 2006, we see a shift from 24 papers mainly focusing on the topic of design education, to 40 papers focusing on processes/practice as well as design cognition. Recently from 2016 and onwards studies on design cognition and design process and practice have been the primary focus in recent years.

Table 3: Design Processes and Practice: Themes and sub-themes in the literature

Design practice & processes (109)	**Definitions**	**Representative papers:**
1. Design activities, strategies (58): **1.1 Ideation (19)** **1.2 Drawing/Sketching (33)** **1.3 Reflective practice (11)** **1.4 Collaborative design (11)** **1.5 Design ability (20)**	**1.1** Ideation: Knowledge sharing/generating ideas **1.2** Drawing/Sketching: a rapidly executed freehand drawing that is not usually intended as a finished work - a tool that allows designers to quickly visualize multiple design concepts **1.3** Reflective practice enables recognition of the paradigms – assumptions, frameworks and patterns of thought and behaviour – that shape our thinking and action. **1.4** Collaborative design is the practice of involving people with distinct backgrounds and mindsets in the design process to achieve non-linear solutions for various kinds of problems **1.5** Design ability: A set of specific abilities and/or skills.	**1.1** Casakin & Levy (2020); Alipour (2021); Viswanathan & Linsey (2013) **1.2** Heyligen et. al. (2009); Cross (2001); Cardella et. al. (2006); Menezes & Lawson (2006) **1.3** Adams et. al. (2003); Ge et. al. (2021); Ellmers & Foley (2020) **1.4** Christensen et. al. (2016); Kleinsmann et. al. (2013) **1.5** Dorst & Reymen (2004); Cross (2011)
2. Problem (105): **2.1 Ill-defined/wicked problems (15)** **2.2 Problem-space (35)** **2.3 Framing (48)**	**2.1** Design problems are usually considered as fundamental examples of ill-defined problems (e.g., Maher and Gero, 1993; Goel, 1995). **2.2** A Problem/Solution space is a set of goals for a creative process. **2.3** Framing is a way of structuring or presenting a problem or an issue.	**2.1** Casakin (2010); Björklund (2013); Self (2017) **2.2**. Bernal (2016); Curry (2017) **2.3** McDonnell (2018); Dorst (2011); Lotz et. al. (2015); Kleinsmann et. al. (2012)
3. Solution (98): **3.1 Fixation (26)** **3.2 Co-evolution (20)** **3.3 Novel(ty) (65)**	**3.1** Fixation impairs ideation for designers and results in impasses. It can also cause the "Einstellung" effect, the phenomenon of overlooking better ways of solving problems. **3.2** The notion of co-evolution has been widely adopted as a useful descriptor of one of the key aspects of designerly thinking: the re-interpreting of a design problem in the light of an exploration of possible solutions until a good 'fit' between problem and solution ('an idea') emerges. A series of unarticulated "Jumps" bridging the gap between the problem space and solution space. Also articulated as jumps between of function and form. **3.3** Novelty refer to something 'new' and 'original'. E.g., a novel solution, idea, or product (in design).	**3.1** Crilly (2015); Lee (2012); Viswanathan & Linsey (2013) **3.2** Lotz et. al. (2015); Bernal (2016); Van der Bijl-Brouwer & Malcolm (2018); Maher & Tang (2003) **3.3** Lawson & Dorst (2005); Alipour (2021)

Table 3, 4 and 5 displays the over-all themes expanded with adjacent subthemes. The tables below do not represent all coded subthemes but a chosen segment of most trending/relevant themes.

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Table 4: Design Cognition: Theme and sub-themes

Design Cognition (88)	Definitions	Representative papers:
Abstraction (44)	In design and art, **abstraction** is the modification of representational forms. Simplification and stylization are methods of abstraction.	Kokotovich & Dorst (2016); Lau (2010)
Analogies (38)	**Analogical design** process consists of either identification, retrieval, mapping, and transference steps.	Moreno et. al. (2014); Alipour et. al. (2017); Casakin (2010); Christensen et. al. (2016); Lotz et. al. (2015)
Designerly ways (21)	The concept of **'designerly ways of knowing'** emerged in the late 1970s in association with the development of new approaches in design education. Professor Nigel Cross first clearly articulated this concept in his paper from 1982.	Cross (1982, 2006); Toyong & Abidin (2021)
Knowledge types (34): **a. Conceptual/Declarative Knowledge (11)** **b. Experiential knowledge (18)** **c. Procedural knowledge (16)** **d. Domain specific knowledge (14)** **e. Tacit/Explicit (13) knowledge** **f. Strategic knowledge (14)**	**Conceptual knowledge** refers to the knowledge of, or understanding of concepts, principles, theories, models, classifications, etc. We learn conceptual knowledge through reading, viewing, listening, experiencing, or thoughtful, reflective mental activity. Also referred to as **Declarative Knowledge.** **Experiential knowledge** is knowledge gained through experience, as opposed to a priori (before experience) knowledge: it can also be contrasted both with propositional (textbook) knowledge, and with practical knowledge **Procedural knowledge** refers to the knowledge of how to perform a specific skill or task, and is considered knowledge related to methods, procedures, or operation of equipment. Procedural knowledge is also referred to as Implicit Knowledge, or know-how. **Domain-specific knowledge** is specialized knowledge of a topic e.g., within one's line of work. **Tacit knowledge** refers to knowledge gained from personal experience that is more difficult to express/Explicit knowledge refers to knowledge that can be verbalized, stored, accessed, and shared with others **Strategic knowledge** refers to a reader's ability to formulate an appropriate purpose and/or logical goal for reading	**(a.)** Neely (2007); Bernal (2016); Ball & Ormerod (2000); Ball et. al. (1997) **(b.)** Kokotovich & Dorst (2016); Tan (2021) **(c.)** Akin (1990); Bernal (2016) **(d.)** Steele (2012); Kim (2019) **(e.)** Curry (2017); Ellmers & Foley (2020); Golja & Schaverien (2007) **(f.)** Popovic & Kraal (2010); Popovic (2003)
Schema/Schemata (knowledge schema, design schema) (25)	A **schema** is a representation of design or idea in the shape of model.	Lawson (2004, 2005); Cross (2018); Casakin (2010); Christensen et. al. (2016)
Situated (design, action, cognition, practice etc.) (44)	**Situated design** acknowledges the tinkering and negotiation involved in designing things — tangible as well as intangible — and making them happen as intended.	Ge et. al. (2021); Kim (2019); Lawson & Dorst (2005); Curry (2017)
Reasoning (Deductive, Inductive, Abductive, Generative etc.) (70)	**Reasoning** as studied in design is presented through selected models of problem solving and design activity. Creative processes involved in idea generation and how such processes can be evaluated are presented.	Dorst (2011); Self (2017) Ozkan & Dogan (2013); Ball et. al. (2004)

Table 5: Design education: themes and sub-themes in the literature.

Design education (73):	Definitions	Representative papers:
4.1 *acquisition* (+ expertise/knowledge, skill, ability, information) (55) **4.2 Learning styles (7)** **4.3 (Design) experience (40)**	**4.1** Acquiring the skill set and abilities to be able to call oneself an expert. **4.2** Learning styles describe how learners gather, interpret, organize, and store information. **4.3** Collecting experience within one's line of work. Experience is normally measured in years of practice.	**4.1** Akin (1990) Tan (2021) Lawson & Dorst (2005) **4.2** Cross (1985) Kim & Kim (2015) **4.3** Ellmers & Foley (2020) Mosely et. al. (2018) Ahmed et. al. (2003)

3.3 The state of art: level of design expertise

In this section we investigate how the study-participants vary and which studies use participants in their research as well as what focus have been to the DE-research. Figure 4 display studies researching levels of design expertise. The numbers in brackets show the total amount of studies in each category. Trending methods and overall themes for the contents of the pyramid are displayed in table 6. Data displayed in the two last rows of table 6, indicate trends for studies researching more than one level of expertise (studies conducting comparative analysis across levels, e.g., comparing students and practitioners). Some papers are coded at several themes while others may be coded at one theme.

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Table 6: DE studies divided upon skill level of participants.

Levels:	Methods applied	Themes	Representative papers:
Design Students (33)	Protocol studies (18) Case studies (6) Mixed methods (4) Interviews (2) Panel data (2) Action research (1)	Design Processes & Practice (25) Design Cognition (17) Design Education (13)	Albers et. al. (2012) Ellmers & Foley (2020) Golja & Schaverien (2007) McDonnell (2016) Mosely et. al. (2018) Sung & Kelley (2019)
Design Practitioners (13)	Interviews, (5) Case studies (5) Protocol studies (2) Panel data (1)	Design processes & practice (12) Design Cognition (5) Design Education (1)	Ball et. al. (1997) Crilly (2015) Van der Bijl-Brouwer (2018)
Design Experts (5)	Interviews, (2) Case studies (2) Action research (1)	Design processes & practice (4) Design Cognition (2) Design Education (1)	Cross & Cross (1998) Cross (2002, 2011) Kim (2019) Ge et. al. (2021)
Experts vs students (8)	Protocol studies (3) Panel data (1) Mixed methods (1) Case studies (1) Action research (1) Interviews (1)	Design Cognition (5) Design processes & practice (5) Design Education (1)	Ahmed et. al. (2003) Toyong & Abidin (2021) Kiernan et. al. (2020) Chervalier & Ivory (2003) Dorst & Hansen (2011) Ozkan & Dogan (2013)
Practitioners vs students (18)	Protocol studies (9) Panel data (3) Mixed methods (2) Interviews (2) Case studies (2)	Design processes & practice (12) Design Education (9) Design Cognition (6)	Björklund (2013) Kleinsmann et. al. (2012) Goncalves et. al. (2014) Ho (2001)

4 DISCUSSION AND RESEARCH IMPLICATIONS

Decentralization of the DE-field: There are many different domains contributing to the field of DE. These domains differ from one another in areas such as design process and core practices, educational background, and the differing emphasis on planning and/or implementation/creation of artefacts of design. The decentralization is adding more diversity and specialized contributions to the field of DE which provides different contexts and perspectives. A downside of this tendency is that it can be challenging to establish an overview of where to start gathering knowledge on DE. It may also prove challenging to identify where research contributions are needed.

Main themes: According to our dataset the main themes are design cognition and design processes and practice. This indicates a high level of focus on the internal and external processes connected to design expertise. Design education is the least included theme which could mean that crucial connections and focus on the transitions between expertise levels are missing from the big picture. Dorst (2004) formulated as a major gap in the literature of DE "At this moment, there is no theoretical basis for explaining and understanding the kinds of transformations the design student must go through, and there is no theoretical basis for identifying the degree of design expertise of a designer at a certain moment. Also, little is known about how to stimulate design expertise development." (Dorst and Reymen, 2004, p. 1). Based on the fact, that most studies are conducting research with student designers as participants, the main assumption would be, that the gap formulated by Dorst (2004) is being addressed by most DE-studies. However, we see that there is a lacking focus on design education in these studies. The implication of not having an educational perspective included in one's research is that researchers are leaving out discussions of the transitional and stimulating role that design education plays for the development of expertise.

Participants in DE-studies: The most frequent studied designers are students and practitioners along with comparative studies of students and practitioners. Less frequent are comparative studies of students and experts as well as expert designers (Laursen and Barros, 2022). Many of the comparative studies of students and practitioners tend to focus on recording and categorizing individual skills of designers through tests in various design tasks and activities e.g., testing specific skills inspired by the model by Dreyfus and Dreyfus (1980), as well as variations such as Lawson and Dorst (2013). While some studies utilize group-testing in DE-research, these tend to consist of participants with similar skill-level rather than a mixture of skill-levels. When looking at the total number of expert studies from

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a set of 110 data sources, we are somewhat surprised to see expert studies being surpassed by studies conducted on students/practitioners, as well as comparative studies on students and practitioners. Considering the emphasis on design processes and cognition (as we discussed in the previous segment) and having design education rated as the least discussed theme, the natural assumption would be to see the pyramid (fig. 5) "flipped". In such a scenario with most expert studies being conducted, it would make more sense to see this prominent focus on design processes and cognitive abilities. However, what we do see is that most studies are conducting tests on design students, while having only marginal focus on the role that design education plays in the context of developing expertise.

Applied methods: The formation of specific patterns can be observed when looking into the methodological trends in Table 6 where both types of comparative studies, as well as studies conducted solely on students, apply the protocol method. We see a shared interest among these types of studies in gathering large datasets as well as including many participants, which correlates with conducting structured research and gathering quantitative data. Research conducted on experts (5) and practitioners (13) mainly consists of interviews and case studies. Again, this correlates with the tendency displayed in these studies, which is using fewer participants as well as seeking more complex answers with a qualitative depth. In expert studies, only three methods are represented which naturally correlates with having only 5 studies represented at the expert level. Regarding papers with a discourse or specific point of critique, these tend to point out shortcomings of the skill acquisition model by Dreyfus and Dreyfus (1980) as the model has a linear view on transitions from novice to expert in design. Moreover, several papers display varied opinions on what defines a non-designer, a novice, and advanced beginner etc.

5 CONCLUSION AND FUTURE RESEARCH

5.1 RQ 1. How has DE developed over time?

There seem to be a decentralization happening within DE-studies, a vast majority of studies displays a tendency of narrowing their focus towards exploring DE in the context of their respective domain. This leaves a vast majority of research contributions covering vertically rather than horizontally to the research on DE. The risk in this type of vertical expansion is that the field is creating a lot of research which holds somewhat little value when looking at the overarching methodological approaches (Laursen and Tollestrup, 2017). The need for studies assimilating findings of the various domains is therefore called for to research the binding factors between them, rather than enhancing the fragmentation into domain-specific contexts.

5.2 RQ 2. What is the focus of DE-literature and how has it evolved?

Looking at the applied methods the protocol studies are heavily relied on in the field. This results in linear and confined perspectives which in many ways seems counterintuitive for studying designers in their "natural environment". Still, few researchers provide critiques on this shortcoming within the field of DE. Based on this observation, we argue that there is room for more studies performed in organic settings by using non-intervening methods rather than fabricating design situations by using protocol studies which, in theory, counteracts the intuitive nature of design situations. Next, our data also shows that the focus of the literature primarily has been on design cognition and processes/practice, while design education has regressed in recent years, which leaves a gap for more research on DE in the context of education. Regarding the levels of expertise investigated, we call for more studies on design experts, as well as more diverse methods in investigating expert designers with a general focus on capturing the totality of their skills in their natural environments. We advocate for more diversity in the participatory arena (e.g., using interdisciplinary or mixed-level groups) and to the methods being applied to the research of design expertise as well as a higher level of critical thinking when applying theoretical models of design expertise. Looking forward our review propose several areas for further research. For example, we encourage more studies of expert designers. Such studies may help progress knowledge building on key points of the 'expertise' in the design profession. Moreover, to understand the situatedness of design, we call for more studies in-situ, for example how experts designers interact with their natural context.

Abbreviations: DE: Design expertise. SLR: Structured Literature Review

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REFERENCES

Ahmed, S. (2007). An industrial case study: Identification of competencies of design engineers. *Journal of Mechanical Design.* Jul 2007, 129(7): 709-716. https://doi.org/10.1115/1.2723807

Alipour, L. (2021). The Relation between Design Expertise and the Quality of Design Idea. *Int. J. Architect. Eng. Urban Plan*, 31(1): 1-11 January 2021. https://dx.doi.org/10.22068/ijaup.31.1.585

Begnum, M. E. N., Pettersen, L., & Sørum, H. (2019). Identifying Five Archetypes of Interaction Design Professionals and Their Universal Design Expertise. *Interacting with Computers*, 31(4), 372-392. https://doi.org/10.1093/iwc/iwz023

Chase, W. G., & Simon, H. A. (1973). The mind's eye in chess. In Visual information processing (pp. 215–281). *Academic Press.* https://doi.org/10.1016/B978-0-12-170150-5.50011-1

Chevalier, A., & Ivory, M. Y. (2003). Web site designs: Influences of designer's expertise and design constraints. *International journal of human-computer studies*, 58(1), 57-87. https://doi.org/10.1016/S1071-5819(02)00126-X

Crilly, N. (2015). Fixation and creativity in concept development: The attitudes and practices of expert designers. *Design studies*, 38, 54-91. https://doi.org/10.1016/j.destud.2015.01.002

Cross, N. (1982). Designerly ways of knowing. *Design studies*, 3(4), 221-227. https://doi.org/10.1016/j.destud.2006.11.003

Cross, N. (1985). Styles of learning, designing, and computing. *Design Studies*, 6(3), 157-162. https://doi.org/10.1016/0142-694X(85)90006-7

Cross, N. (2001). Design cognition: Results from protocol and other empirical studies of design activity. *Design knowing and learning: Cognition in design education*, 79-103. (613) https://doi.org/10.1016/B978-008043868-9/50005-X

Cross, N. (2006). Design as a discipline. Designerly Ways of Knowing, 95-103. *Springer London*. https://dx.doi.org/10.1007/1-84628-301-9_7

Cross, N. (2011). Design thinking: Understanding how designers think and work. *Berg Publishers*. https://dx.doi.org/10.5040/9781474293884

Cross, N. (2018). 21 Expertise in Professional Design. *The Cambridge Handbook of Expertise and Expert Performance*, 372. https://doi.org/10.1017/9781316480748.021

Dorst, K. (2004). On the problem of design problems - problem solving and design expertise. *Journal of design research*, 4(2), 185-196. https://doi.org/10.1504/JDR.2004.009841

Dorst, K. (2011). The core of 'design thinking 'and its application. *Design studies*, 32(6), 521-532. https://doi.org/10.1016/j.destud.2011.07.006

Dorst, K & Reymen, I 2004, Levels of expertise in design education. in P Lloyd, N Roozenburg, C McMahon & L Brodhurst (eds), *Proceedings of the 2nd International Engineering and Product Design Education Conference, 2-3 September 2004, Delft. Delft University of Technology, Delft*, pp. 159-166, 2nd International Engineering and Product Design Education Conference, IEPDE 2004, Delft, 2/09/04

Dreyfus, S. E., & Dreyfus, H. L. (1980). A five-stage model of the mental activities involved in directed skill acquisition. *California University, Berkeley Operations Research Center*. https://dx.doi.org/10.21236/ada084551

Ellmers, G., & Foley, M. (2020). Developing expertise: Benefits of generalizing learning from the graphic design project. *International Journal of Art & Design Education*, 39(2), 461-475. https://dx.doi.org/10.1111/jade.12260

Ericsson, K. A., Hoffman, R. R., Kozbelt, A., & Williams, A. M. (Eds.). (2018). The Cambridge handbook of expertise and expert performance. *Cambridge University Press*. https://dx.doi.org/10.1017/CBO9780511816796

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological review*, 100(3), 363. https://dx.doi.org/10.1037//0033-295X.100.3.363

Ericsson, K. A., & Smith, J. (Eds.). (1991). Toward a general theory of expertise: Prospects and limits. *Cambridge University Press*. SBN 13: 9780521406123

Gray, C., & Siegel, M. (2014). Sketching Design Thinking: Representations of design in education and practice. *Design And Technology Education: An International Journal*, 19(1). Retrieved from https://ojs.lboro.ac.uk/DATE/article/view/1925

Gulari, M.N. 2015. Metaphors in design: how we think of design expertise. *Journal of research practice [online]*, 11(2), article M8. Available from: http://jrp.icaap.org/index.php/jrp/article/view/485/423

Guthrie, J., Ricceri, F., & Dumay, J. (2012). Reflections and projections: a decade of intellectual capital accounting research. *The british accounting review*, 44(2), 68-82. https://dx.doi.org/10.1016/j.bar.2012.03.004

Huang, Y., & Li, J. (2015). Comparing personal characteristic factors of imagination between expert and novice designers within different product design stages. *International Journal of Technology and Design Education*, 25(2), 261-292. https://dx.doi.org/10.1007/s10798-014-9276-x

Jagtap, S. (2018). Shaping products: Differences between expert and novice industrial designers. *In 15th International Design Conference, Design* 2018, *Dubrovnik* (Vol. 5, pp. 2229-2240). The Design Society. https://dx.doi.org/10.21278/idc.2018.0159

Kim, S. T. Y. (2019). Understandings of professional communication design expertise: a phenomenographic study (*Doctoral dissertation, RMIT University*, 2019).

Kuosa, T., & Westerlund, L. (2012). Service design: On the evolution of design expertise. ISBN: 978-951-827-155-3

Laursen, L. N., & Barros, M. (2022). Timely and timeless framing of the new MINI Cooper. *Design Studies*, 82, 101123. https://doi.org/10.1016/j.destud.2022.101123

Laursen, L. N., & Tollestrup, C. (2017). Design thinking-a paradigm. *In DS 87-2 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 2: Design Processes, Design Organisation and Management, Vancouver, Canada, 21-25.08*. 2017 (pp. 229-238).

Lawson, B. R. Y. A. N., & Dorst, K. (2005). Acquiring design expertise. In: Gero, J.S. and Maher, M.L. eds., 2005. *Computational and Cognitive Models of Creative Design VI: Reprints of International Conference of Computational and Cognitive Models of Creative Design VI, Heron Island, Australia, 10-14 December 2005*. *Key Centre of Design Comp & Cogntn*. https://dx.doi.org/10.1007/978-94-017-0793-0_19

Lawson, B., & Dorst, K. (2013). Design expertise. *Routledge*. https://doi.org/10.4324/9781315072043

Lee, J. S. (2012). Design knowledge and expertise: A comparative analysis of novice to professional fashion designers. *Cornell University ProQuest Dissertations Publishing* 2012, 3520173.

Light, R.J. and Pillemer, D.B. (1984), Summing Up, *Harvard University Press*, Boston, MA.

Lotz, N., Sharp, H., Woodroffe, M., Blyth, R., Rajah, D., & Ranganai, T. (2015). Framing Behaviors in Novice Interaction *Designers. Design and Technology Education: An International Journal*, 20(1). https://dx.doi.org/10.13140/2.1.1158.6880

Massaro, M., Dumay, J., & Guthrie, J. (2016). On the shoulders of giants: undertaking a structured literature review in accounting. *Accounting, Auditing & Accountability Journal*. Vol. 29 No. 5, pp. 767-801. https://doi.org/10.1108/AAAJ-01-2015-1939

Massaro, M., Dumay, J., & Garlatti, A. (2015). Public sector knowledge management: a structured literature review. *Journal of knowledge management*. Vol. 19 No. 3, pp. 530-558. https://doi.org/10.1108/JKM-11-2014-0466

Mclaughlin, S. (2012) Design Expertise Practices and Affordance, in Israsena, P., Tangsantikul, J. and Durling, D. (eds.), Research: *Uncertainty Contradiction Value - DRS International Conference* 2012, 1-4 July, Bangkok, Thailand.

Mosely, G., Wright, N., & Wrigley, C. (2018). Facilitating design thinking: A comparison of design expertise. *Thinking Skills and Creativity*, 27, 177-189. https://doi.org/10.1016/j.tsc.2018.02.004

Oluwatayo, A. A., Ezema, I., & Opoko, A. (2017). Development of Design Expertise by Architecture Students. *Journal of Learning Design*, 10(2), 35-56. https://dx.doi.org/10.5204/jld.v10i2.268

Petre, M. (2009, August). Insights from expert software design practice. *In Proceedings of the 7th joint meeting of the European software engineering conference and the ACM SIGSOFT symposium on The foundations of software engineering* (pp. 233-242). https://doi.org/10.1145/1595696.1595731

Popovic, V., & Kraal, B. (2010). Expertise in software design: Novice and expert models. *In Proceedings of the Studying Professional Software Designers: An NSF (National Science Foundation)-Sponsored International Workshop* (pp. 1-7). University of California. https://dx.doi.org/10.1017/CBO9780511816796.021

Rusten, G., & Bryson, J. R. (2007). The production and consumption of industrial design expertise by small-and medium-sized firms: some evidence from Norway. *Geografiska Annaler: Series B, Human Geography*, 89, 75-87. https://dx.doi.org/10.1111/j.1468-0467.2007.00261.x

Schön, D.A. (1983) The reflective practitioner: How professionals think in action. *New York: Basic Books, Inc*. https://dx.doi.org/10.4324/9781315237473

Smith, K. M. (2015). Conditions influencing the development of design expertise: As identified in interior design student accounts. *Design Studies*, 36, 77-98. https://dx.doi.org/10.1016/j.destud.2014.09.001

Stacey, M. K., Eckert, C. M., & Wiley, J. (2002). Expertise and creativity in knitwear design. *International Journal of New Product Development and Innovation Management*, 4(1), 49-64.

Steele, C. (2012, January). The effects of background upon engineering design expertise and producing more competent engineering design students (a Sino-occidental comparison*). In Proceedings of 'The Profession of Engineering Education: Advancing Teaching, Research and Careers', The 23rd Annual Conference of the Australasian Association for Engineering Education* (pp. 909-917). Melbourne, Victoria, Australia: Australasian Association for Engineering Education. https://dx.doi.org/10.4028/www.scientific.net/AMM.215-216.452

Tan, S. (2021). Towards an integrative approach to researching design expertise. *Design Studies*, 74, 101017. https://dx.doi.org/10.1016/j.destud.2021.101017

Wetter-Edman, K., & Malmberg, L. (2016, May). Experience and expertise: key issues for developing innovation capabilities through service design. In Service Design Geographies. *Proceedings of the ServDes. 2016 Conference* (No. 125, pp. 516-521). Linköping University Electronic Press. (19)

Yilmaz, S., & Daly, S. R. (2016). Feedback in concept development: Comparing design disciplines. *Design Studies*, 45, 137-158. https://dx.doi.org/10.1016/j.destud.2015.12.008