NORDDESIGN CONFERENCE
REYKJAVIK, ICELAND, 12-14 AUGUST 2024

A Conceptual Model of Industrial Design Practice

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Abstract: Disruptive technologies such as Generative AI, Additive Manufacturing, Computational Design, Industry 4.0, and the Internet of Things, have the potential to transform Industrial Design practice. To investigate this transformation, a model of design practice is necessary as a research and methodological tool. In this paper, we review the main contributions that defined the elements of design practice and based on the literature propose an overall model. The building process of the model and the model of design practice itself contribute to capturing real-life design practices and infer new theoretical constructs to understand how innovative technology is impacting design processes, design tools and relationships with clients and customers. Through the analysis of those elements, this paper proposes a conceptual model to support further studies on the evolution of Industrial Design and Product Design.

Keywords: Design Practice, Industrial Design, Design Tools

1 Introduction

The literature on industrial design presents two approaches to define the elements of professional practice. A significant stream of literature theorised industrial design as a logical and rational process highly dependent on the knowledge, skills, and judgement of the individual designers along with the circumstances of the context and environment (Stolterman, 2008a). Another stream attempted to capture the best practices in the industry and turned them into methods that other designers could use (Daalhuizen et al., 2019). These so-called practice-generated methods emerged from the professional practice intended to create commercial products (Goodman et al., 2011), where professional industrial designers provided solutions supported by their personal experience and knowledge, emphasised by iterative processes (Paik et al., 2019). During the years, these approaches have been superseded by new models such as those proposed by Sanders and Stappers (2008). While these contributions had the benefit of modelling the new perspectives and approaches (Boeijen et al., 2014) that were emerging within industrial design practice, many aspects of the traditional approach to industrial design are still widely adopted in industry.

Nowadays, disruptive technologies such as Generative AI, Additive Manufacturing, Computational Design, Industry 4.0, and the Internet of Things, have the potential to further transform Industrial Design at the operational, functional, and professional levels.

To support the research efforts into understanding the evolution of industrial design and product design practice, this paper reviews and collates into a cohesive conceptual model the past attempts which have defined and modelled traditional design practices. Our model aims to provide a conceptual framework and a practical research tool to support design researchers in investigating emerging design practices and comparing them with traditional ones thus delineating how the practices of industrial and product design are transforming.

The theoretical model is developed based on the definitions of Industrial Design Practice taken from the literature. The paper adopts a purposeful sampling (Birks et al., 2015) activity that identified 23 studies that proposed a definition of Industrial Design Practice. Then a theoretical sampling was performed to identify the first set of common terms used to describe Design Practice and develop a model with the recollected concepts and relationships. Finally, a conceptual model of Industrial Design Practice is presented and discussed.

2 Perspectives on the definition of industrial design practice

As the literature that attempts to define Industrial Design Practice is scarce, and an agreed definition is fragmented, a literature review (Kitchenham and Charters, 2007) was undertaken to identify all relevant definitions. The review comprised distinct activities that involved:

- The formulation of a review protocol,
- the collection of relevant documents,
- the review and exclusion of irrelevant studies,
- and the analysis and synthesis of the remaining studies.

During the formulation of the review protocol, relevant keywords were identified along with the inclusion and exclusion criteria, the search strategy, data organisation, analysis and synthesis. Keywords, inclusion and exclusion criteria were directly derived from the research questions and the aims described above. The general keyword “Design Practice” was used in the automatic search to identify as many relevant studies as possible.

Searching specifically for publications that quote “Design Practice”, in the title, the abstract or the body of the paper, related to areas of manufacture, product design, or industrial design. The search was performed including the site's Web of Sciences and Scopus, resulting in the selection of 23 documents that specifically described in a paragraph or paragraphs the terms or elements of Design Practice. Snowballing was adopted when relevant references were identified in the original papers.

Research articles (from journals and conferences) and books written in the English language and published from January 1995 to February 2023 were included in the study. Documents not related to the topic of Design Practice and documents such as editorials, prefaces, poster sessions, panels and tutorial summaries were excluded. Further, when different versions of an article were found, only the most complete version was considered.

The literature analysis papers aimed to identify a set of concepts, and terminology to describe design practices in the contexts of product design, industrial design, and engineering design. The examination consisted of the review of each paper and the identification of the specific concepts, terminology and words used to describe a design practice or an interpretation of a design practice. The outcome of this analysis is presented in the table “extract of literature review analysis” included in Figure 1. The table identifies the author, paper title, publication year, journal, domain, keywords, extract (the paragraph or paragraphs from where the design practice description is identified), including as a summary, the words, terms or concepts (that describe the design practice), and in the last column the number of citations of the publication in Google Scholar, and Web of science.

No.	Author	Journal title	Year	Published on	Domain	Keywords	Extract	Summary	Citations
1	Erik Stolterman	The nature of design practice and implications for interaction design research	2008	International Journal of design V2 N.1	Interaction design	Design Research, Interaction Design, Nature of Design	Dealing with a design task in an unknown or only partially known situation, with demanding and stressed clients and users, with insufficient information, with new technology and new materials, with limited time and resources, with limited knowledge and skill, and with inappropriate tools, is a common situation for any interaction designer. Dealing with such messy and “wicked” situations constitutes the normal and everyday context of any design practice	(1) Design Task, (2)clients, (3) information, (4) technology, (5)materials (6) product strategy (7) plans.	Citations on Google Scholar 720, citations on Web of Science 217
2	Richard Buchanan	Surroundings and environments in fourth order design	2019	Design issues: Vol 35 Number 1 Winter 2019	Design Theory		Early in the twentieth century, designers initially found their problems and opportunities in the two large fields of communication and production. One field was mass communication through signs, words, images, and symbols. Work in this field led to the innovation of Graphic Design—the creation of a design practice to provide type, layout, and images for newspapers, books, journals, magazines, posters, brochures, and other print media that served the purpose of communicating information, texts, and arguments for society. The second field where designers found their problems and opportunities early in the twentieth century was mass production: the creation of all the artifacts or physical objects, of whatever scale, that facilitate our living. Work in this field led to the innovation of Industrial Design—the creation of a design practice that provided the plans and prototypes upon which the constructions of industrial mass production could proceed.	(1) Plans, (2) Prototypes, (3) Industrial mass production	Citations on Google Scholar 26, citations Web of Science 6

Figure 1 Extract from the literature review analysis.

Following the identification of the terms and concepts and terms used to describe design practice an analysis of the frequency of a word used in the papers, found that the most used word to describe design practice is “plan” followed by “skills and knowledge” and later “context”.

Then followed by eight terms that include, “prototypes and models”, “process”, “materials” and “tools” and additionally “instructions and techniques”; followed by “product artefacts and things”, sketches, blueprints, and design activities. The analysis of the literature suggests that since industrial product design emerged as the profession for the creation of plans to mass-produce artefacts or physical objects (Buchanan, 2019), design practitioners work in close contact with disciplines such as engineering, ergonomics, business, aesthetics, social sciences, and humanities. However, architects, engineers and industrial designers have their own “esoteric” knowledge codes woven right into their practices (Schön, 1983). The activity of designing consists then of conceiving planning and dreaming up something that will subsequently be brought into existence following its guidelines (Waks, 2001). The product of design professionals' activity is captured in the form of sketches, scores, blueprints, plans or programs. In this sense, design practice is a profession of pre-conceptualization for subsequent execution (Waks, 2001).

Terminology	Qty of papers	
Design project	1	4%
Manufacture	1	4%
Technology	2	9%
Desing task	2	9%
Designer or Design teams	2	9%
Iteration	2	9%
Design problem & solution	2	9%
Methods	3	13%
Information	3	13%
Clients	3	13%
Function & form	3	13%
Design Activities	4	17%
Sketches, blue prints	4	17%
Product, artifacts & things	4	17%
Instructions & techniques	5	22%
Tools	5	22%
Materials	5	22%
Design Process	5	22%
Prototype & models	5	22%
Context	7	30%
Skills & Knowledge	8	35%
Plan	9	39%

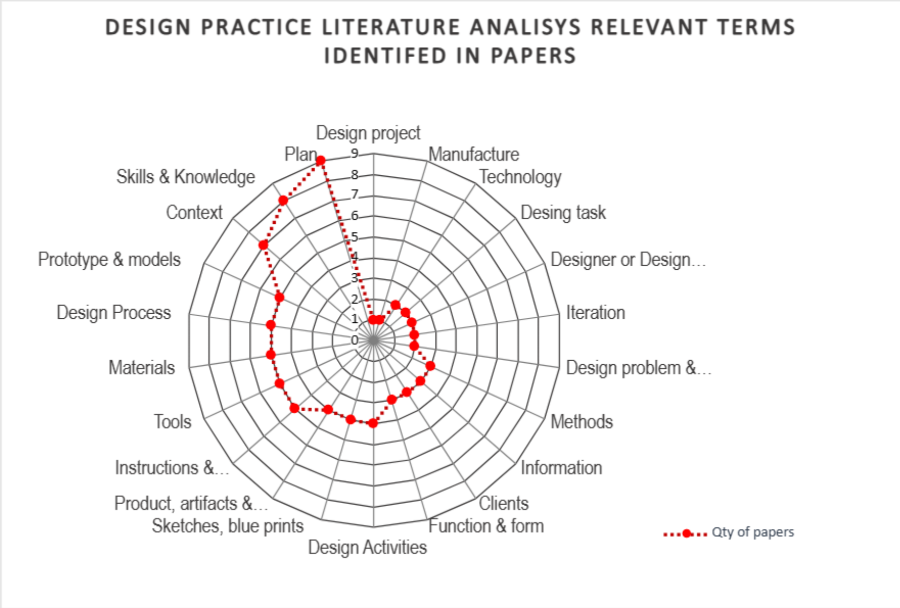

Figure 2 Relevant concepts of Design Practice identified in the literature analysis.

3 Building a conceptual model of industrial design practice.

A model is a conceptual representation of an object, process, or system that can be verified, analysed, and manipulated for a specific purpose. While models don't exist in the real world, their construction provides a means to gain understanding, exercise control, and facilitate learning about the systems they represent (Smith and Morrow, 1999a)

Modelling is the act of producing appropriate models of a system, through the fundamental act of abstraction that allows analysis, exploration, and refinement. It is a valuable tool that enables to analyse and predict the behaviour of those activities and processes that may be too costly or time-consuming to understand in their actual conditions.

The Badham (2010) compendium of modelling techniques suggests four stages for the implementation of models: Initialization, Design, Build and Confirmation. The Initialization stage consists of the definition of the problem, which assesses the relevance of the system components and relationships. The Design stage implies an agreement on the factors or elements to be included and the assumptions on those to be excluded. The objective of the design phase is to teach the modellers how the system operates (Badham, 2010). During the build phase, if the model is implemented to communicate and understand the key features of the system, the design document may constitute the model and no separate build phase is required (Badham, 2010). The confirmation stage is required to confirm that the model is reasonable. Here it is important to check if the question originally asked is illuminated by the model (Badham, 2010). In the case of a conceptual model like the one developed in this study, the stage of application, the model and documentation are presented to the research community for discussion and comment.

3.1 Initialization and problem formulation

This phase identifies and analyses the terminology as reported in the literature of design practice.

The literature review found five main definitions of Industrial Design Practice. According to Dorst and Van Overveld (2009), a comprehensive description of Design Practice includes the object of its activity, the problem and emerging solution, the actor (designer, design team, or designing organization), the context in which the activity takes place, and the structure and dynamics of the design process being studied (Dorst, 1997; Reymen, 2001).

Cherkasky (2004) summarizes the constitutive elements of the Design Practice as the understanding of how design problems are framed, how the design activity is structured, and how artefacts and other material resources are configured. Stolterman (2008b) asserts that Design Practice is constituted of five interrelated features: the design task, customers and users, materials and technology, knowledge and skills, and tools. As proposed by Wynn and Clarkson (2017), a model of Design Practice offers insights into the design practitioners' activities at various levels. Such a model captures key concepts and helps understand relationships between identified components and elements thus making design practice more transparent and comprehensible. Their suggested model emphasises elements of Design Practice such as processes, terminology, and representations.

3.2 Design of the conceptual model

After the identification of the terminology used in the literature for describing design practice, an affinity diagram analysis was used to generate group clusters of data based on their natural relationships (Awasthi and Chauhan, 2012). The grouping was carried out by identifying the common terms, and the relationships between those terms. The steps adopted for developing the affinity diagram include: (1) Implementation of written cards, A digital tool (Miro board) was used to implement the written cards, (2), Grouping the cards with similar or equal terms (within the digital space of the Miro board as shown in Figure 3). (3) Clustering the cards and reaching a consensus. (4) To finally produce the affinity diagram.

Figure 3 Extract from Affinity diagram.

The outcome of the affinity diagram is a set of 10 terms to be used in the model. Starting with the designer or design teams; planning, skills, and knowledge; user and environment; including, design tools and methods; design tasks and activities; technology, materials, and manufacturing, and finally Products or services. During the discussion to reach a consensus the following relationships were defined:

- *Prescribes*: To dictate, direct; to make a ruling.
- *Defines*: To determine the boundary or spatial extent of; to settle the limits of.
- *Uses*: The act of putting something to work or employing or applying a thing.
- *Performs*: To carry out, to execute.
- *Selects*: To choose in preference.
- *Develops*: To bring into being.
- *Considers*: To think carefully or seriously about.
- *Learns*: To acquire knowledge and skills.

In this study, a (1) designer is defined as a professional overseeing the design process and executing design tasks using design methods. Industrial designers, often responsible for a significant portion of the entire design activity (Ulrich, 2011), are members of a team that includes engineering designers, manufacturing engineers, software developers, and other professionals with specific technical skills (Coates et al., 2002).

(2) Design Problem, the design problem involves reasoning from a set of needs, requirements, and intentions to create a new physical structure with an intended use (Dorst, 2004).

(3) Plan, according to the Oxford Dictionary, a plan is an organized and detailed proposal outlining how something is to be done, serving as a scheme of action, strategy, program, schedule, or method of proceeding. Project planning translates a project's mission goals and performance measures into a feasible plan, linking the conceptual design phase to the production phase (Shtub et al., 2005). O'Donovan et al. (2005) distinguish three forms of planning: initial planning at the project's beginning, operational planning throughout the project, and dynamic planning to modify original plans in

response to unexpected events. Although individual designers use plans for day-to-day work, most plans offer only rough process guidance (O’Donovan et al., 2005).

(4) Skill, skill is the capability to accomplish something with precision and certainty, combining practical knowledge with ability (Oxford Dictionary). Design skills, including cognitive, technical, and behavioural characteristics related to design practice, can be acquired through training, education, and practice (Kamila Kunrath et al., 2020). The literature identifies eight main skill elements: Cognitive Abilities and Strategies, Personal and Interpersonal Communication, Education-based and Practice-based knowledge, Managerial Competency, and Project Management (Kang et al., 2015; Krawczyk and Murphy, 2012; K Kunrath et al., 2020)

(5) Knowledge, knowledge is the fact or condition of having acquired practical understanding and competence in a particular subject. In product design, an innovation-intensive process, substantial knowledge, and design experience are required (Zeng and Horváth, 2012). Designers utilize existing solutions and knowledge, making analogies between current design problems and retrieved results to generate new solutions (Hargadon and Sutton 1997), with knowledge reuse and recombination proven to be the prime source of innovations (Guan and Yan, 2016; Liu et al., 2020; Strumsky and Lobo, 2015).

(6) Context, context refers to the circumstances in which an event occurs. The product design context encompasses factors influencing customer attribute preferences, including product usage, customer, stakeholders and market contexts (Green et al., 2008).

(7) Tools, in the context of design, tools are implements that facilitate the use of a method or aid in the use of a method. For example, a manual or computer-based systematic method or framework, has the potential to increase efficiency in one or several phases of the development process (Norell, 1996).

(7a) Design Methods, design methods encompass procedures, techniques, aids, or tools used by designers during the design process. They represent various activities used and combined in a design process, including conventional procedures like technical drawings and recent non-conventional procedures categorized as "design methods" (Cross, 2021).

(8) Design Activities, design activities include understanding client needs (including market analysis), writing design specifications, generating, and evaluating concepts, developing schemes (embodiment of concepts), and evaluating detailed designs for manufacturing (Eckert and Clarkson, 2005).

(8a) Design Task, the design task description contains statements about product functionality, performance, deadlines, and costs (Pahl et al., 2007).

(9) Technologies, Ulrich and Eppinger (2016) identify two kinds of technologies: In a market-pull situation, a firm begins product development with a market opportunity and uses available technologies to satisfy the market need. In developing technology-push products, the firm begins with new proprietary technology and looks for an appropriate market in which to apply this technology (Ulrich and Eppinger, 2016). (9a) Materials, materials, as the matter or substance from which a thing is made, require an understanding of their behaviour under expected operating conditions (Clarkson and Eckert, 2005). (9b) Manufacture, design for manufacture (DFM) specifies design rules to improve production conditions, aiming to increase a product’s manufacturability. incorporating manufacturing issues into product design choices, utilizing information such as sketches, drawings, product specifications, design alternatives, detailed understanding of production and assembly processes, and estimates of manufacturing costs, production volumes, and ramp-up timing (Ulrich and Eppinger, 2016).

(10) Design of products and services. Designers, according to Krippendorff (2005) and Verganti (2003) use material artefacts to reinterpret or reimagine products and services for new contexts, users, or markets. A product is something sold by an enterprise to its customers (Ulrich and Eppinger, 2016).

3.3 The Model of Industrial Design Practice

The overall model of Industrial Design Practice is presented in Figure 4.

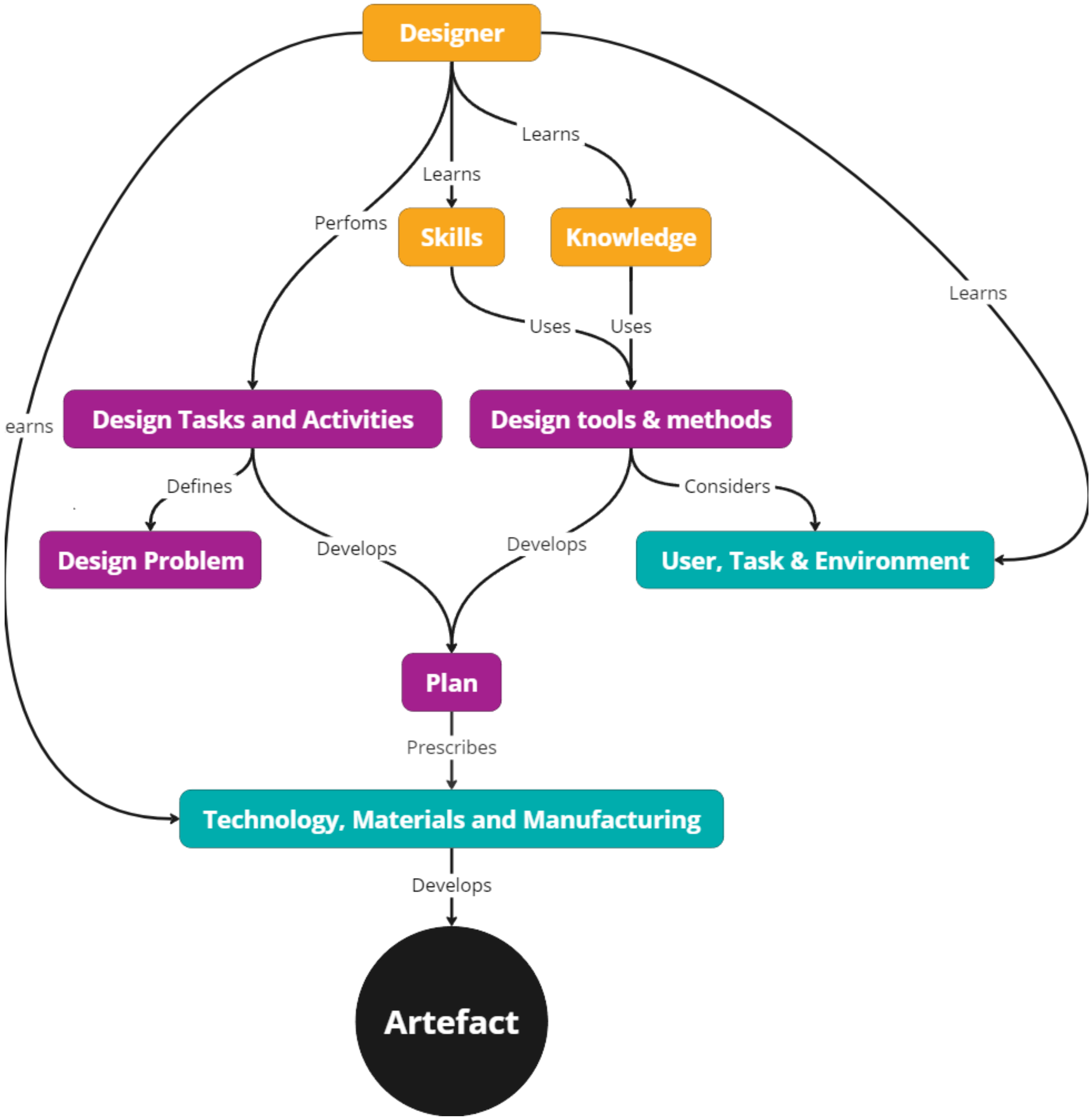

Figure 4 Conceptual Model of Industrial Design Practice.

The model produced in this study presents the key elements of Industrial Design Practice. The model suggests that most practitioners are concerned with having a strategic view of the design project through a plan, making sure the project is within the limits of their skills and knowledge and their understanding of the context of how and where the product will be used. Design practitioners also observe the need for tools and methods to implement the design process, which may drive the construction of prototypes, and the selection of appropriate technologies, materials, and manufacturing techniques.

Design practitioners also identify design activities. Their reflections relate to sketches and blueprints used to learn about the product, communicate and provide information to clients and other designers. The analysis also shows that only a few of them identify as part of the processes of practice, the design task, iterations, design problem and solutions, and technology.

The modelling approach provides an understanding of different facets of a problem. Both the process of model building and the model itself provide a systematic way of developing a more comprehensive understanding of key aspects of a problem (Badham, 2010).

The data for constructing the cases will be gathered from diverse sources, including recorded interviews with professional designers; artefacts such as sketches, virtual and physical prototypes, end-use products; and photos, field notes and documents portraying the context. The findings will be built by analysing each case individually and incrementally to build a rich set of themes until saturation and validation of the proposed model among the new findings.

3.4 Confirmation

The confirmation stage requires the confirmation that the model is reasonable and that the model elucidates the original question asked.

The discussion and the modelling implementation, including the stages of identifying the terminology used to describe the design practice, led to the conclusion that the model is reasonable and answers the original question, providing an integral view of the elements of design practice found in the literature, however, the analysis also makes evident that proper validation and confirmation of the model require a deeper investigation of the design practice, including the professional design practitioners, thoughts, reflections and opinions about their professional activity.

3.5 Application

In practice, the applicability of models and methods is limited by their product or process-focused perspective. Activities and processes in design and development processes related to individual activities and their context including those associated with the flow of tasks and design progression and those related to project/programme and contextual considerations, require significant coordination (Wynn et al., 2019). Modelling is a valuable tool that enables to analyse and predict the behaviour of those activities and processes that may be too costly or time-consuming to understand in their actual conditions (Eckert et al., 2010). A model is a conceptual representation of an object, process, or system that can be verified, analysed, and manipulated for a specific purpose, their construction provides means to gain understanding, exercise control, and facilitate learning about the systems they represent (Smith and Morrow, 1999b).

Within the terminology used to describe Industrial Design Practice, the term plan is used to identify a strategy and to refer to the development program, or schedule. Linking strategically the different stages of the development process, from the conceptual design phase to the production phase (Shtub et al., 2005). Designers use managerial and project management skills defining, how to do the work (the strategy) and to organise tasks and activities (the development program). The literature also suggests that design practitioners use their cognitive, technical, and behavioural skills to perform the design work.

By using their educational and practice-based knowledge, in addition to their cognitive skills, professional designers utilise design methods, techniques, aids and tools to perform design activities identifying user needs (Cross, 2021). Retrieving existing design solutions and knowledge, designers make analogies to generate new solutions (Smith and Morrow, 1999b), within market, customer, and user contexts. Design practitioners, use knowledge, skills, and methods to generate and evaluate concepts, to develop schemes (embodiment of concepts) and detailed designs (Eckert and Clarkson, 2005).

The design task, on the other side, contains statements about the product's functionality and performance including deadlines and costs (Pahl et al., 2007), these statements imply the use of available technologies to satisfy a market opportunity or to search for the appropriate market to apply a proprietary technology. Including the selection and use of adequate materials (Clarkson and Eckert, 2005).

4 Discussions and Conclusions

In summary, this model of Industrial Design Practice suggests that most design practitioners are concerned with having a strategic view of the design project through a plan, making sure the project is within the limits of their skills and knowledge and their understanding of the context of how and where the product will be used. Design practitioners also observe the need for tools and methods to implement the design process, which may drive the construction of models and prototypes, materials selection, instructions, and techniques. Design activities relate to sketches and blueprints used to learn about the product, communicate and provide information to clients and other designers. The analysis also shows that only a few of them identify as part of the processes of practice, the design task, iterations, design problems and solutions, and technology.

The implementation of a model of design practice paves the way for research into real-life Industrial Design Practices building new theoretical constructs through the analysis of activities and processes of industrial designers. Developing a detailed understanding of how the technology, processes and context are transforming design practice, including its relationship to products and customers, The model enables the capture of key concepts, understanding relationships, providing insights at different levels, and enhancing visibility and transparency. Through thematic, content and artefact analysis uncovering new themes, hypotheses, and theories, the study pioneers the research on the impact of emerging practices in product design activity, providing the methodological foundations for a longer research effort aimed at understanding the impact of emerging technologies, tools, and methods in the current industrial design practices. Future work will need to be carried out to understand other topics of Design Practice, and particularly those related to the designer-costumer relationship such as challenging the brief and negotiating conflicting situations.

5 Acknowledgement

This work was supported by the Arts and Humanities Research Council [grant number AH/V009214/1].

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