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Study of Methods for Documenting Product Features and Evaluating Their Quality in Industrial Design Theses

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Abstract

In recent years, the intense competition across various industries has significantly increased companies' focus on product design and development. Researchers and designers have increasingly recognized the importance of adopting efficient design and development processes, as highlighted by various studies and training programs. Identifying the exact characteristics of a product based on users' real needs forms the foundation of the research and development process, preceding production discussions. Clear and accurate articulation of product specifications is crucial for effective communication between design and production teams, as well as decision-makers. This research has been conducted to clarify efficient and effective ways of extracting product specifications in order to reach a common language between designers, engineers and production agents. For this purpose, by reviewing the studies, the requirements raised in this regard were discussed and the necessary parameters were extracted regarding the correct way of expressing the product specifications. These parameters included five instructions regarding the writing of specifications and the necessity of determining the measurement index and ideal and marginal values in each specification. In the following, by examining several industrial design bachelor's theses, the degree of conformity of the specifications expressed by the designers and the parameters extracted from the research was measured. The findings indicate that the most prevalent inconsistency in product specification documentation (observed in 59.9% of the analyzed theses) stems from inadequate consideration of user needs' granularity when articulating design criteria. Also, some designers face a challenge in determining the index to measure some specifications, which requires the need to acquire more knowledge and experience in this field. It is suggested that the necessity of using these components in expressing product specifications and accuracy in determining indexes should be taken into consideration by designers and trainers in this field.

Keywords

Product Design and Development, Industrial Product Specifications, Design Evaluation Methods, User Needs.

Introduction

Design often refers to an activity carried out by a thinking agent, intentionally creating a plan. A design is a concept of an object, process, or system that possesses specific characteristics and detailed features. Design problems vary in complexity across different fields, especially in recent years with the emergence of new technologies, which have significantly increased these complexities. Therefore, due to the high complexity and broad dimensions of design and product development, the design process generally requires the collaborative work of specialists with diverse scientific and skill-based backgrounds. Product design often takes shape in multidisciplinary teams, including designers, management experts, marketing professionals, engineers, and production specialists. Industrial design can play a significant role in the development of innovative products. However, integrating design thinking into new product development comes with challenges, as industrial designers often have very different perspectives and goals compared to other team members, which can lead to misunderstandings and tension (Micheli et al., 2012).

According to the definition provided by the Industrial Designers Society of America (IDSA), industrial design is a professional service of creating products and systems that optimize function, value, and appearance for the mutual benefit of both the user and the manufacturer (IDSA, 2009). Industrial designers gather product information through analysis, and this data is recorded and expressed in the form of product characteristics. These characteristics are then applied to create a new and efficient design, and the final design is presented through clear and comprehensive descriptions, using drawings, models, and prototypes. The transfer of information and decision-making plays a crucial role in the product development process. Information must be continuously retrieved, processed, and analyzed. Supporting the product development process is the primary responsibility of design methodology, knowledge management, and tools (Freddi et al., 2019).

Industrial designers serve as interdisciplinary bridges, balancing aesthetic, functional, and technological considerations. While engineers focus on technical parameters and manufacturability, and marketers emphasize commercial appeal, designers integrate these dimensions through user-centered solutions. This divergence in perspectives often creates decision-making challenges requiring shared terminology. Successful product teams leverage these complementary viewpoints as strategic assets (Kleinsmann et al., 2012).

Despite the strong emphasis on the necessity of conducting design research in the process of designing and developing products, as well as the diverse design processes presented, there are limited studies on the integration of design processes within different perspectives. Due to the diversity in various fields of design research — such as mechanical engineering, production, art and design, architecture, management, and others— different perspectives on design research and its methods have developed in parallel (McMahon, 2011). It is essential to facilitate discussions and dialogues among various communities involved in design and product development through multiple studies. This will allow for the examination of areas of agreement, similarity, and difference among them, and will help identify opportunities for greater collaboration in design to enhance development and impact in industries and societies.

Effective product feature documentation is recognized as a critical factor in the success of product design teams. International experiences demonstrate that industry leaders such as Apple (Saffer, 2010), through the implementation of *user experience-based feature mapping*, have achieved significant results in aligning design requirements with production needs. This approach is also acknowledged in the automotive industry as an effective solution for addressing engineering challenges and facilitating agile manufacturing (Ågren et al., 2019).

IKEA's standardized visual documentation system employs intuitive diagrams and graphic symbols to represent product features, enabling simultaneous comprehension by both end-users (as text-free assembly instructions) and design-production teams (as precise technical references; Garvey, 2011).

Similarly, domestic manufacturers have achieved comparable outcomes through localized approaches. Mapna's intelligent dynamic documentation platform enables real-time recording of technical specifications in complex projects, with automated detection of design-production conflicts, providing tangible benefits for both design engineers (in parameter optimization) and execution teams (in reducing manufacturing errors; Tahanpour et al., 2024). Iran Khodro's integrated technical-commercial documentation framework utilizes a dual-level specification format that concurrently addresses engineering requirements (e.g., engine torque) and market needs (e.g., 0-100 km/h acceleration; Davari, et al., 2021). These cases collectively establish that structured documentation methodologies not only minimize production errors but also create a shared language among multidisciplinary stakeholders.

Design is a non-linear activity and must be reconfigured to adapt to the various stages that constitute the design problem (Chen & Terken, 2023). The design problem is often described as a *wicked problem* (Rittel & Webber, 1973), which is the main factor distinguishing design research from other sciences and also the primary reason for the lack of design process models. A *wicked problem* is extremely difficult to solve due to its incompleteness, contradictions, and changing requirements. Every design is a creative process; no matter how many theories and principles exist, there is always a certain degree of uncertainty (Rittel & Webber, 1973).

A successful designer must be able to understand their users while also having a thorough awareness of various technical possibilities and a good sense of aesthetics (Brown, 2009). Identifying users and their diverse needs regarding a product is one of the fundamental steps in any design process (Kolko, 2014). This is especially true if the need is hidden; Cross (2011) refers to such needs as the user's non-verbal thoughts. The primary goal of this stage in the process is to enable designers to develop a deeper understanding of the design problem and translate this understanding into components that will later serve as design criteria and decision-making tools for the final design. Typically, various user research methods are employed at this stage, such as ethnographic observations (Crabtree et al., 2012) and different types of interviews and surveys (Goffin et al., 2010). Additionally, there may be requirements from the client or project owner, from previous projects (since complex systems are not always designed from scratch), or from the marketing department (Chen & Terken, 2023). Therefore, the designer must strive to understand the fears, desires, and motivations of users by observing individuals, their environment, and their behaviors. The next stage is idea synthesis or generation in the design process. Using their design skills and a wide range of design methods, designers transform potentially complex components into designs and ultimately decide, through precise evaluation methods, what to emphasize and what to overlook.

Sharp et al. (2019) describe the design process as consisting of four fundamental activities:
1. Formulating design components
2. Designing multiple solutions
3. Prototyping
4. Evaluation.

As evident from examining various approaches to the design process, determining design components based on user needs is the most initial and essential stage in the design process. Any mistake at this stage can lead to significant losses in the design and production of the product. The defined characteristics serve as guidelines during the idea generation phase, and designers can draw inspiration from these characteristics to create innovative designs. Additionally, during the evaluation phase, the product characteristics are used as criteria to select the design that best aligns with user needs and other design requirements (Chen & Terken, 2023). Therefore, various sources emphasize not only the necessity of collecting accurate and factual data in this regard but also the importance of properly articulating these components and requirements (Ulrich & Eppinger, 2016). These components also referred to as target product specifications, provide a precise description of the product's capabilities in an ideal state. The articulation of these characteristics must be precise and measurable to create a suitable foundation for mutual understanding among the design team members. In this way, design team members can have greater confidence in achieving the desired outcome (Ulrich & Eppinger, 2016).

Design activity, due to its complexity and high sensitivity, requires education as both a skill and a field of knowledge. Individuals can acquire industrial design skills and techniques by attending training courses, universities, and educational institutions. Education in this field includes design principles, the use of software, methods, and industrial design processes, as well as business principles related to industrial design. The foundation of any design process is the development of a list of product characteristics, which must be formulated in a way that is understandable to all members of the design and production teams. Therefore, it is expected that industrial design students at universities will gain sufficient expertise in this area.

Modern designers must utilize new technologies that are still evolving. They need to gain a deep understanding of social issues, human behavior, sustainability, diverse cultures, value systems, and modern business models. Understanding users and the various dimensions of their lives is essential for achieving precise product features. Many user needs, expressed as product features, are emotional, psychological, and cognitive needs that are often not easily articulated and are rarely measurable through quantitative methods. For example, a user expects a product to be user-friendly and easy to use. However, this is a general statement, and when a designer describes a product feature in this way, it does not provide specific details about what constitutes ease of use for the audience. Clearly, the precise articulation of these features can significantly influence the formation of design ideas and the evaluation of proposed designs. Despite the high importance of this issue, it has not yet been sufficiently addressed. It seems that designers and other members of product design and development teams lack the necessary familiarity with effective tools for mutual understanding of product features.

In our country, due to the high importance of the issue of production development and its related infrastructure, addressing this matter is of great significance. By investing in production infrastructure and creating a suitable platform for research and development, as well as fostering effective collaboration among experts and various production stakeholders, we can contribute to the formation and strengthening of the production sector and increase productivity. Most available resources in the field of knowledge management and design and production documentation are foreign, which has created a significant challenge for experts and engineers working in our country's production sector. Additionally, the fragmentation of information and knowledge in this field makes it difficult for designers and engineers to access a comprehensive and complete set of information, forcing them to search through numerous and scattered sources.

Compiling a list of user needs, as well as interpreting and translating user need statements into target product features, is the foundational step of the design process. This step must be formulated with great precision, as the final design is shaped based on the criteria extracted and derived from these needs. This task is highly challenging and requires skill and experience, often posing difficulties for industrial design students and designers. To address this, the present study, by reviewing previous research, examines the necessity of focusing on knowledge management in industrial design and methods for documenting product features. Then, by searching through undergraduate theses in this field, it seeks to answer the following question: *What common mistakes are observed in the formulation and writing of target product features by industrial design students?* Revealing these shortcomings in design projects guides educators in this field toward providing effective strategies for improving this process.

This study adopts a mixed-methods (qualitative-quantitative) approach, structured into two main sections:

1. The theoretical section: Framework for Documentation Principles in Product Design

2. The practical section: Evaluating the implementation of documenting principles in academic case studies.

In the theoretical section of the research, the main objective is to explain methods of knowledge management in industrial design and to examine methods of documenting product features. To achieve this objective, a comprehensive review of authoritative sources (including scholarly articles, specialized books, and industrial standards) was conducted to extract a theoretical framework comprising key principles for documenting product features.

Knowledge management involves the collection, organization, and sharing of knowledge and information related to the design and development of products.

Theoretical Section: Framework for Documentation Principles in Product Design

1. *Theoretical Foundations and Research Background*

The theoretical foundations related to knowledge management in industrial design encompass various theories that explain methods and tools for knowledge management. These theories include different models for collecting and organizing knowledge — such as the Design Rationale approach (Moran & Carroll, 2020), which captures the reasoning behind design decisions to support future retrieval and reuse, and the Knowledge Intensive Design (KID) model (Blessing & Chakrabarti, 2009), which emphasizes integrating domain-specific and process-related knowledge throughout the product development process. Moreover, knowledge management plays a pivotal role in ensuring that relevant information flows efficiently across the different stages of the design process — from conceptualization to production— by supporting informed decision-making and traceability. They also address methods for transferring knowledge among design team members and technological tools to support knowledge management (Anderson et al., 2024). Due to the extensive range of topics within design processes, this study excludes detailed exploration of individual design stages. Instead, the primary focus of the research is on methods of documenting design criteria, which should be integrated and clearly and systematically recorded in the design documentation or product dossier for designers, engineers, and manufacturers.

2. *Product Design Process*

The process of product design can be described as a procedure in which the designer, with the help of various product data, makes design decisions and transforms a set of functional requirements into a specific executable structure (Wiley & Baxter, 2018). Product design is an iterative and complex process, often divided into sub-processes, each involving different tasks. Design tasks require continuous iteration, and during this period, a significant amount of data support is needed (Riesener et al., 2021). In the product design process, there are four main stages: needs analysis, conceptual design, physical design, and detail design. Each stage of the product design process has its specific activities, involving relevant personnel and departments, and generates a large amount of data (Dieter, 1991). These are presented in Table 1.

Table 1: *Four Main Stages of the Design Process Based on Dieter's Model (1991).*

Needs Analysis	Conceptual Design	Physical Design Design	Detail Design
Based on the product features obtained from the previous stages, the product is modeled in full detail. A prototype is built and tested to accurately determine its alignment with user requirements	Engineering aspects, materials, physical structures, dimensions, production methods, and other technical details are examined and determined. The goal of this stage is to transform the conceptual design of the product into a manufacturable physical prototype and ensure that it is sufficiently practical and producible	The conceptual design model of the product is built based on design data and knowledge. Multiple proposed solutions in response to customer needs are examined and combined to achieve an optimal solution (Pahl & Beitz, 2013).	Based on customer needs and market data, an analysis of key customer priorities is conducted and formulated into product features and characteristics. Accurately identifying user requirements is the core focus of needs analysis (Feng et al., 2020).

Considering the model presented above, which is widely agreed upon by experts and designers, it is evident that product features derived from user requirements form the basis for generating ideas and evaluating designs. If sufficient care is not taken in documenting these product features, the design and, consequently, the produced product may face shortcomings.

3. *Knowledge Management and Documentation of Studies in Product Design Processes*

The question *What is knowledge?* can have various answers, as this term carries different meanings even within the context of engineering and design. Knowledge is not directly accessible but is derived through the interpretation of information inferred from data analysis.

Data, in the form of observations, computational results, and measurable quantities, are available to an organization. The interpretation, abstraction, or association of this data leads to the generation of information. Ultimately, knowledge is acquired through experience and learning from this information and putting it into practice (Owen & Horváth, 2002). In fact, by looking at engineering design from a teleological perspective, it can be said that the primary function of engineering design research should be to transform empirical or rational knowledge into a form that can be used for practical purposes. The classification of knowledge, much like the understanding of knowledge, is crucial for determining ways to represent it. In the context of design and engineering, knowledge can be classified across several dimensions. Owen and Horváth (2002) have identified two main categories of knowledge in the field of design and engineering: explicit knowledge and tacit knowledge. Explicit knowledge is embedded in product documents, resources, descriptions of product functionality and structure, problem-solving procedures, technical and management systems, computer algorithms, expert systems, and so on. These provide the necessary intellectual foundation for the construction and production of a product. On the other hand, knowledge related to experiences, intuition, unarticulated models, or implicit general rules is referred to as tacit knowledge.

Knowledge in the domain of design and engineering can also be discussed concerning either the product or the design process. Product knowledge encompasses various types of information and knowledge related to the evolution of a product throughout its lifecycle. This includes requirements, relationships between parts and assemblies, geometry, functionality, behavior, various constraints associated with the product, and design logic. Process knowledge can be divided into design process knowledge, manufacturing process knowledge, and business process knowledge. Design process knowledge, which can be encoded as methods in product representation, provides mechanisms for realizing design details at various stages of the product lifecycle. Manufacturing process knowledge is primarily defined by activities related to production (Candlot et al., 2008). Business process knowledge encompasses all processes related to marketing, strategic planning, supply chain management, finance, and other related tasks. While product knowledge and process knowledge are not independent of each other, they represent distinct aspects of dimensions and are therefore generally considered separately.

Therefore, a good product design support tool should have the capability to capture knowledge not only through the design process but also be able to represent it in a way that reflects the appropriate context. Thus, a significant portion of research in the field of product design is dedicated to the capture, representation, and reuse of knowledge in a manner that is efficient and effective for advancing design objectives and enabling all members of the design and development team to understand its various concepts.

Documentation of studies in industrial design can serve as a critical process for collecting, storing, and transferring information and knowledge throughout the industrial design process (Elgh & Söderfeldt, 2010). There are various methods for documenting studies in industrial design. Owen and Horváth (2002) classify knowledge representation methods in this field into five categories: visual, symbolic, linguistic, virtual, and algorithmic.

- Visual: Two-dimensional representations of products and sketches, drawings, models, diagrams, etc.
- Symbolic: Decision tables, process diagrams, flowcharts of the design process, etc.
- Linguistic: User needs and requirements, design constraints, user feedback, etc.
- Virtual: CAD models, virtual reality, etc.
- Algorithmic: Mathematical equations, computer algorithms, design and manufacturing processes, etc. (Chandrasegaran et al., 2013).

In all the models and methods of knowledge representation mentioned in the categories above, we need consistent and systematic principles to achieve conceptual integration among individuals involved in the design process. Access to these principles is more challenging in verbal methods due to the diversity of languages and terminologies. For example, despite communication mechanisms, researchers have observed that industrial designers and engineering designers still do not fully understand each other.

For instance, the same words may not carry the same meaning or two different words may have the same meaning. Communication becomes precise and effective only when the team establishes a shared vocabulary and understands the communication codes and language within the context of the message (Kim & Lee, 2014). By examining various design processes, some of the most commonly used methods for knowledge representation and documentation in design activities are listed below:

- Report Writing: One of the simplest methods for documenting studies in industrial design. Reports can be used to accurately and systematically record the results, methods, activities, and analyses of studies (Hesse et al., 2016).
- Using Design Notebooks: In industrial design, design notebooks are often used to record ideas, creative outputs, descriptions, and the progress of work (Park & Saczynski, 2018).
- Using Videos and Images: Videos and images can effectively document and share the design process, experiments, and experiences (Chandrasegaran et al., 2013).
- Using Software and Tools: Various software and tools are used in industrial design to record and document studies. These may include information management software, modeling and simulation systems, and design and analysis software (Elgh & Söderfeldt, 2010).
- Using Knowledge Management Systems: In industrial design, knowledge, and experiences are highly valuable and must be properly recorded and managed. Knowledge management systems can help in capturing and sharing knowledge and experiences (Kim & Kim, 2011).

User Needs Analysis Based on Systematic Methods

The primary motivation for developing a product is to meet customer needs, and these needs serve as the direct driving force behind data-driven product design. Methods for analyzing customer needs typically rely on systematic approaches and data processing to interpret and address customer requirements. Below are some common methods used in this field:

- Voice of the Customer (VOC): This refers to the collection of customer opinions, expectations, and needs. This information is gathered through customer feedback, user experiences, surveys, discussions, and other communication channels. The goal of collecting the Voice of the Customer is to gain a deeper understanding of customer needs and preferences to provide products and services that genuinely meet their demands. VOC may encompass various aspects, including needs and priorities, expectations, past experiences, criticisms and suggestions, emotions, and emotional experiences (Edinger-Schons et al., 2020).
- Kano Method: This is a quality management model that analyzes and interprets customer needs and preferences regarding product features. The Kano method is particularly useful for prioritizing and enhancing product features in the design process. By categorizing user needs concerning different products and services, the Kano method helps product design teams make informed decisions about feature prioritization and strategically improve their products' competitive positioning in the market. The key components of this model include basic features, performance features, and unexpected (delight) features (Madzík et al., 2024).
- QFD Method: Quality Function Deployment (QFD) is a documentation method used in industrial design to translate customer needs and desires into technical specifications and product features. The main steps of this method include collecting customer requirements, translating customer needs into product features, converting product features into subsystems and system components, and finally transforming subsystems into specific elements (Ginting et al., 2020).
- FMEA Method: Failure Mode and Effects Analysis (FMEA) is a technique used to identify and analyze potential failures and their causes in the industrial design process. The primary objective of this method is to prevent errors and issues in processes or products. The main steps of this method include identifying the stage or product, identifying failure modes, evaluating failure effects, assessing the likelihood of occurrence, calculating failure rankings, and proposing and implementing corrective actions (Wu et al., 2021).

- TRIZ Method: This method is used to document strategies and approaches for problem-solving and innovation in the industrial design process. The key principles of TRIZ include the following: innovation, combination and adaptation of elements, contradictions and trade-offs, and problem indicators (Sojka & Lepšík, 2020).
- DMAIC Method: This method is a complementary approach within Six Sigma, used for managing and improving processes in industrial design. Through this method, studies related to defining, measuring, analyzing, improving, and controlling processes are systematically documented. The stages of this process are as follows: Define, Measure, Analyze, Improve, and Control (Bhise, 2023).

Types of Requirements and Needs in Product Design

To achieve a precise and unified understanding of product features within design and development teams, it is essential to establish a common language for expressing design requirements and product characteristics. In the book by Bhise (2023), various requirements in product design are categorized and introduced as follows:

Table 2: *Various requirements in product design.*

Type of Requirement	Description
Customer Requirements	Define customer (or stakeholder) expectations of the product or system based on its mission, objectives, functions, environment, and constraints.
Functional Requirements	Specify the functions that must be performed to achieve the product's objectives (i.e., its operation or usage). This includes details such as what needs to be done, when it should be done, and how it should be executed.
Performance Requirements	Define the extent to which a mission or function must be executed, typically measured in terms of quantity, quality, coverage, timeline, or readiness.
Interface Requirements	Specify the capabilities that must exist within a given interface between systems, subsystems, or components to ensure the proper functioning of the product.
Reliability Requirements	Can be defined as the probability of a product, system, subsystem, or component operating without failure for a specified period under defined operational conditions.
Environmental Requirements	These requirements are intended to control the adverse effects of the environment on individuals, products, or systems under which the product or system is designed to operate. All environmental concerns must be considered.
Human Factors Requirements	A set of needs and criteria designed to ensure that humans, as operators or maintainers of the product or system, can perform assigned tasks and functions with ease and comfort. Human abilities, characteristics, and limitations must be considered throughout the design process.
Safety Requirements	These requirements are designed to ensure the safe operation of the product or system. Safety is generally defined as the absence of accidents or hazardous situations that could lead to adverse health effects, injuries, loss of life, or damage to property.
Security Requirements	Ensure that the product is not accessible to unauthorized individuals or those who may pose a threat to the product or its systems.
Compliance with Design Requirements	In general, a product should be designed to meet its stated requirements while accounting for potential variations in characteristics (or parameters) resulting from the manufacturing process.

Principles of Stating Requirements in Product Design (Product Features)

To determine whether a requirement is *good* (i.e., useful, unambiguous, and feasible), several characteristics must be considered. Therefore, the considerations for creating a *good* requirement are as follows (Bhise, 2023):

1. The requirement statement should clearly describe what needs to be done.

2. The requirement must be unambiguous, clearly stated, and complete. It should explicitly specify what needs to be accomplished, the success criteria, and the conditions under which it applies. It should be formulated in a way that minimizes confusion and differences in interpretation among various individuals (especially engineers). To ensure completeness, the requirement should provide contextual details such as status, environment, operational conditions, duration, urgency/priority, and user characteristics under which the product is expected to function.

3. The requirement should use consistent terminology when referring to the product and its lower-level entities.

4. The requirement should explicitly state its applicability (i.e., when, where, types of systems, hierarchical system levels where it applies, and where it does not apply).

5. The requirement must be verifiable through a specific test, test equipment, test method, and/or independent analysis.

6. The requirement must be feasible (i.e., the development of the system or product should be possible without excessive time and cost).

7. The requirement should be consistent with and traceable to other higher- and lower-level requirements within the system hierarchy.

8. Each requirement should be independent of other requirements. This characteristic helps control and reduce variability in product parameters and, consequently, in its performance.

9. Each requirement should be concise, meaning it should be stated with minimal informational content.

Ulrich and Eppinger (2019), highlighting that design requirements are derived from the interpretation of user statements regarding products, recommended that the interpretation process be conducted by a team of experts. To this end, they provided five guidelines. The first two are fundamental and crucial for effectiveness, while the remaining three ensure consistency in phrasing and style:

- State the requirement in terms of what the product must do, rather than how it might do it. Customers often express their preferences by describing a solution concept or an implementation approach. However, requirement statements should be independent of any specific technological solution.
- Express the requirement as specifically as raw data. Requirements can be stated at different levels of detail. To prevent loss of information, the requirement should be expressed at the same level of detail as the raw data.
- Use positive statements rather than negative ones. When a requirement is stated as a positive statement, it is easier to translate it into product specifications. However, this is not a rigid rule, as positive phrasing can sometimes be difficult or awkward. For example, *The thermostat does not require battery replacement* is naturally more suited to a negative phrasing.
- State the requirement as a product feature. Expressing requirements as statements about the product ensures consistency and facilitates their translation into product specifications. However, not all requirements can be clearly expressed as product features; in most such cases, they can be framed as user-related product characteristics.
- Avoid using *must* and *must not*. Instead, it is essential to define a level of importance for the requirement.

The Importance of a Common Language in Product Design

The complexity of modern design processes and the involvement of various stakeholders have highlighted the necessity of a common language in product design. Design data encompass numerous elements, which, in the theoretical framework, are referred to as design knowledge. The need for learning, teaching, and utilizing experiences necessitates the documentation of all studies conducted within a design process. However, in the absence of a shared language for expressing concepts, understanding them becomes challenging and prone to errors for those participating in the design process. Generally, the objective of these approaches is to enhance communication, stimulate idea generation, and bridge the gap between customer needs and technical requirements in the product design process.

Methodology

Practical Section: Evaluating the Implementation of Documenting Principles in Academic Case Studies

The first part of this study follows a review-based approach. By examining various sources, different design processes and knowledge management methods in product design were identified. This section aims to consolidate existing knowledge on documenting design studies, offering an in-depth exploration of methodologies to guide designers and researchers toward standardized practices.

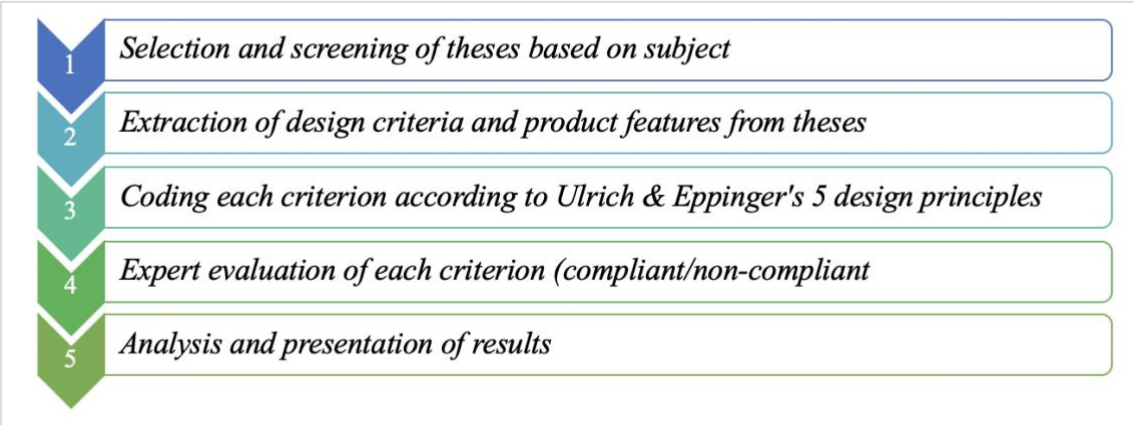

Figure 1: *A systematic process for evaluating design documentation quality in academic projects.*

The second part employs a descriptive-analytical documentary approach. To assess industrial design students' understanding of the subject, undergraduate theses in industrial design were examined. Given the diverse range of thesis topics, knowledge management approaches varied accordingly, which was beyond the scope and objectives of the present research. This study specifically focused on how product features were documented in undergraduate theses with similar topics related to product design. Subjects such as furniture, packaging, digital tools, and other design-specific themes were excluded from the analysis.

Table 3: *The evaluation sheet for Thesis #37.*

Document code:37						
The general topic of the thesis:		**Design of a rechargeable brush for sinks**				
		Avoid using *must and should*	Feature of the product itself	Positive statement	Stated with details	What is not how to achieve it
Product criteria and features	Minimalist design of the brush compartment	✓	✓	✓	✗	✗
	The flexible brush head capability allows access to hard-to-reach areas.	✓	✓	✓	✓	✗
	Extendable handle capability for versatile applications	✓	✓	✓	✓	✗
	Rechargeable capability for whole-home usage	✓	✓	✓	✓	✗
	Lightweight	✓	✓	✓	✗	✗
	Built-in detergent storage compartment	✓	✓	✓	✗	✗
	Must have sufficient strength	✗	✓	✓	✗	✓
	The material must be plastic to ensure water resistance.	✗	✓	✓	✓	✗
	The brush handle won't break under normal use.	✓	✓	✗	✓	✓
	Other device's rechargeable batteries are replaceable with the product batteries.	✓	✗	✓	✗	✓
	Multiple brush heads for cleaning different areas	✓	✓	✓	✗	✗

To evaluate the application of relevant guidelines, 140 undergraduate theses in industrial design from universities specializing in this field in the country were randomly selected, covering the period from March 21, 2016, to September 22, 2021. A total of 229 theses with the specified characteristics were reviewed, and based on Morgan's table, a sample size of 140 was determined. The sections related to product requirements and features were extracted and rewritten from the selected theses. These were then examined by a panel comprising industrial design faculty members, professional designers, and practicing engineers. The number of extracted guidelines varied across different theses, with a total of 2,114 guidelines identified from the 140 theses, all of which were thoroughly analyzed. The practical implementation of this study followed a systematic five-stage process, as illustrated in Figure 1.

For each thesis, a comprehensive evaluation document was prepared, containing all extracted design criteria and product features. These documents were reviewed by the evaluation team, and their compliance (or non-compliance) was recorded in the relevant tables. Table 3 provides an example of this assessment.

Findings

Based on the five general guidelines for interpreting raw data into user requirements, as mentioned in the theoretical section, the extracted and prioritized design guidelines from undergraduate industrial design theses were analyzed. The results of this study indicate the following:

- Out of 2,114 analyzed guidelines, 1,050 cases (49.67%) did not comply with Guideline 1, which states that *the requirement should describe what the product must do, rather than how it should do it.*
- 1,560 cases (73.79%) failed to adhere to Guideline 2, which requires that *the requirement be stated exactly as raw data*.
- 380 cases (17.98%) did not follow Guideline 3, which recommends *using positive statements instead of negative ones*.
- 412 cases (19.49%) did not comply with Guideline 4, which suggests that *requirements should be expressed as product features*.
- 1,880 cases (88.93%) failed to meet Guideline 5, which advises *avoiding the use of words like must and should*.

Figure 1 illustrates the frequency distribution of the 2,114 analyzed guidelines based on non-compliance with the essential principles for interpreting raw data into user requirements.

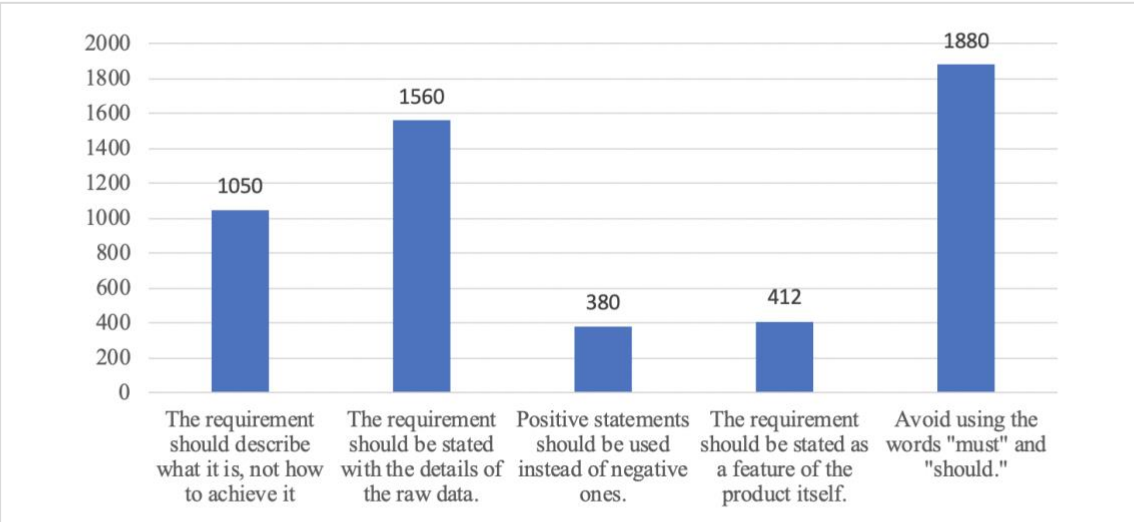

Figure 2: *The distribution of the 2,114 analyzed design guidelines based on non-compliance with the necessary points in interpreting raw data into user requirements.*

Statistical analysis shows that students pay the least attention to the guideline *avoid using the words must and should" when interpreting raw data into user requirements (approximately 89% did not comply). In contrast, the highest attention in adhering to the necessary guidelines in interpreting raw user data is given to the guideline "use positive rather than negative statements* (approximately 18% did not comply).

Additionally, based on the three main characteristics that the target product features must have, the product design guidelines written in the selected undergraduate theses were examined. The results of this study revealed that out of the 2,114 analyzed guidelines, 1,261 (59.65%) adhered to Characteristic 1, which is *the specification of criteria for each feature*, while 895 (42.34%) followed Characteristic 2, which is *the specification of an acceptable value for the desired feature*. Furthermore, 213 (10.08%) complied with Characteristic 3, which is *the specification of the ideal value for the desired feature*. Figure 2 shows the distribution of the 2,114 analyzed design guidelines based on adherence to the expected specifications in writing the target product features. According to this chart, the highest compliance is related to Characteristic 1, which is *the specification of criteria for each feature*,"while the lowest compliance is associated with Characteristic 3, which is *the specification of the ideal value for the desired feature*.

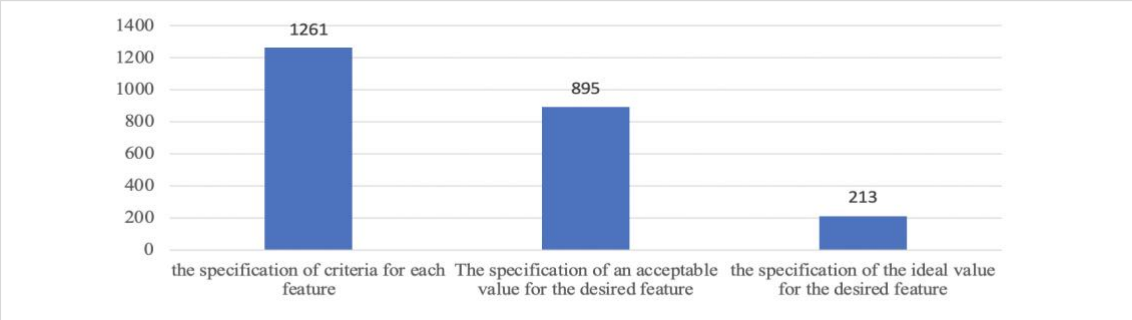

Figure 3: *Distribution of the 2,114 analyzed design guidelines based on the degree of deviation from user requirement guidelines in interpreting raw data.*

Statistical analysis shows that students pay the least attention to the ideal value of the desired feature when writing the target product features (approximately 10%). In contrast, the greatest focus is placed on defining the criteria for the desired feature (approximately 60%). The specification of the acceptable value for the desired feature was followed in approximately 42% of the cases.

Conclusion

The world today faces new challenges. Designing and producing customer-compatible products offers a competitive advantage to manufacturing companies and is essential in some industries. Designers are beginning to play larger roles in larger organizations, not only in design but also in managing and making decisions about activities that need to be carried out across the business. Despite the vast diversity of design projects, design generally serves a common goal: the development of new products and services. Each design process aims to meet the real needs of users while also addressing business needs within the constraints of health, safety, and environmental requirements. Each product has specific functions, positioning, and features. The clearer the product features are identified, the more the product's value can be created and enhanced (Tsang et al., 2022). Clearly, any shortcomings or mistakes in this process may lead to failures and irreparable costs for companies.

For years, industrial design education in universities and institutions has been striving to organize design studies and integrate the related knowledge to achieve design goals. Student theses are accessible documents that those interested in acquiring design knowledge often refer to. Unlike proprietary documents from companies or private designers, which are often classified or confidential, student theses are generally made available through institutional repositories or online platforms, making them a valuable resource for design-related knowledge.

However, while efforts have been made in education, significant gaps remain in practical implementation, as evident in the challenges designers face. The topic of documenting design studies has not yet reached an optimal level of integration, and few studies at global universities have evaluated thesis writing (Eisenmann et al., 2021). This situation has led to most researchers and designers not being sufficiently aware of the integrated methods for documenting design studies, particularly in the section of product features, which plays a crucial role in the design process (Knauss, 2021).

In this research, the importance of documenting data and product features in the industrial design process and the need for a common and standardized language and writing style for designers and students were examined. Through library studies and analysis of multiple sources, the research indicates that having a shared language and standardized writing method can play a very effective role in improving the design process and reducing errors. Design knowledge management, discussed in this study, aims at standardizing concepts in the design and production process, thus enabling the study and experience of stages and processes. In the second part of the research, common mistakes made by final-year industrial design students in implementing product features as design criteria were examined.

The results showed that industrial design students in the universities studied lack a precise understanding and awareness of a shared language in expressing product features. The major shortcomings found in the industrial design undergraduate theses in the section on design guidelines indicate a lack of mastery by industrial designers in knowledge representation methods in design and engineering fields.

It seems that despite the highly advanced capabilities of designers in presenting innovative and beautiful designs, an effective communication system has yet to be established for interacting with other sections of the design team. This issue may stem from various reasons, some of the most important of which include: the lack of a common language and communication standards, overemphasis on the product design aspect compared to the necessary studies for design, the absence of an integrated training system, and content for the design process across different fields, cultural and linguistic differences, time pressures, and stress (Smulders & Dunne, 2017).

Designers may use intuitive approaches and creative processes to solve problems, seeking opinions beyond the ordinary and considering diverse perspectives. On the other hand, engineers often focus on technical specifications and industry standards. Failure to pay attention to details such as ideal and acceptable values and indicators when expressing product features leads to engineers and production teams lacking a clear understanding of the stated features. Upon closer examination of the types of features most affected by this issue, it was observed that many of them relate to aesthetics, appearance, and human factors (Murray et al., 2019). Unlike functional and operational features, for which indicators can be more easily defined, these features lack tangible and measurable indicators. Nevertheless, it is essential to propose suitable indicators for evaluating these features. Achieving such rules requires collaboration between industrial design associations and engineers to develop actionable guidelines for defining subjective and emotional indicators in these contexts (Daly et al., 2018). Finally, it is recommended that more details about such issues in documenting design studies be extracted by examining theses and design documentation that these issues be included in the research agenda for design scholars.

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