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The Impact of Artificial Intelligence AI in Enhancing Experience Design of Physical Products

Prof. Ahmed Waheed Moustafa
Emeritus professor, Design and Ergonomics, Faculty of Applied Arts, Helwan University, ahmedwms@hotmail.com
Prof. Mahmoud Abdel Nabi Muhammad
Professor of Design, Department of Metal Products and Jewelry, Faculty of Applied Arts, Helwan University, mahmoudahmed1964@gmail.com
Amira Mohammad Mohammad Essawy
Ph.D. Researcher, Freelance designer, Department of Metal Products and Jewelry, Faculty of Applied Arts, Helwan University, AmiraMuhammad@a-arts.helwan.edu.eg

Abstract

This study investigates the integration of Artificial Intelligence (AI) in the experience design of physical products to enhance customer engagement and satisfaction. Focusing on products characterized by repetitive use, low complexity, and high production volumes, the research aims to evaluate both the advantages and challenges of using AI in product design. The study explores how AI-driven approaches can improve the user experience by creating emotionally resonant, memorable interactions through AI-enhanced sensory and interface touchpoints. By using scenario-based research, the study examines how AI can co-design customer experiences alongside designers, contributing to the Physical Design Cycle. The approach is rooted in human-centered design principles, emphasizing the importance of AI in fostering emotionally enriching, personalized user experiences while addressing ethical considerations. Through a literature review and empirical field study, this paper presents an analysis of AI's role in improving experience design across UX, product aesthetics, and smart products. The findings suggest that AI holds substantial potential to transform the design process, enhance consumer engagement, and shape future design practices in academia and industry, setting a foundation for future research.

Keywords

Artificial Intelligence AI, Experience Design XD, Physical Products, Product Design.

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1. Introduction

This study explores the use of Artificial Intelligence (AI) to enhance customer experiences in product design. This requires the investigation into the benefits and drawbacks of incorporating AI into physical product design processes and understanding the designer's approach to benefit from AI partnership in product development. The study focuses on spatially and temporally discrete interactions with repetitive-use, low-complexity, high-production-volume physical products. The research aims to explore the potential of AI in creating engaging customer journeys and explore the potential of AI in the design process (Yüksel et al.2023).

In the evolving customer experience landscape, both physical and digital contact points are becoming increasingly important. The tangible physical product contributes to human memory building, while interactive sensory touch points and interface mechanisms store personal thoughts, making moments into lifetime memories. These moments are valuable to new customers and businesses from repeat and recommended business. The engineered journey's strategic parallel research investigates customer-suggested co-design evolving journey aspects inserted into the phases of the informative Physical Design Cycle. Conceptual scenario thinking is undertaken to extend technology-enhanced tangibly memorable moments of experiences, potentially extending into the future emotional lifetime of valuable tangible customer heritage. This is consequential for human health and well-being. The engineered journey's research investigates customer-suggested co-design evolving journey aspects and incorporates these aspects into the informative Physical Design Cycle. This approach aims to create experiences that are both memorable and beneficial for both new and repeat customers (Rasool et al., 2020).

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This research aims to explore how AI technologies can improve the experience design of physical products, particularly digital products such as video displays, computer workstations, and handheld wireless information tools. Experience design in the service sector focuses on creating a coordinated environment of people, furnishings, signals, and smells that unfold over time. As energy accelerates this design process, qualitative markers of change are needed to identify impact. AI is a powerful force for change, and it is time to explore the synergies of intelligence, intentional design, and value. The paper is presented in four chapters, starting with a background on AI and current thinking about experience design. The second chapter defines key terms, while the third explores current intelligence, particularly in human-machine hybrids. The fourth section uses these definitions and findings to develop a value statement, and the final section transposes findings to provide an alternative lens for judging the societal implications of artificial and wider-known intelligence (Ameen et al., 2021).

1.1. The Significance of Experience Design in Product

Design The practice of design has always evolved to cater to the needs of the user. Over the years, design objectives have shifted from efficiency and practicality to user- and human-centric values. The perspective of design has been continuously changing and has proven to be inclusive and interdisciplinary. It has become somewhat simple, clear, accessible, and sometimes unstable due to the ever-changing nature of the boundaries. At its inception, designing services and experiences started from the same positions adopted by user-center d design and user experience. Service design includes different practices nowadays, especially in the private domain of practices and consulting. Still, experience design has become a method, concept, and toolkit also in academia and research (Dengel et al., 2022). Experience design is a human-centric design practice that aims to enhance the emotional pleasure of users in various fields such as game marketing, intelligent user interfaces, and tangible interaction design. Traditional user experience cannot provide a comprehensive experience design for all product users due to its opaque and personal elements (Huang & Rust, 2021). However, artificial intelligence technology has emerged, allowing for more accurate and personalized experience design. This research uses a prototype of an AI-powered holistic experience design tool to support industrial product designers in making informed decisions about integrating experiential properties of products. The tool can reason as a human designer, and the paper serves as the basis for an AI comparative test. The research also includes the research of experts in the field (Chang and Kuwata2020).

The Internet of Things (IoT) has revolutionized the way physical products are connected to the internet, enabling new services and experiences. Technological advancements in information and communication technologies, smart materials, sensors, and actuators have enabled almost all products to be connected to the internet. As communication becomes possible, new rules will guide products, with artificial intelligence being a major driving force. The IoT aims to become a change agent, enabling new services and experiences to emerge. The development of IoT products is influenced by technological advancements and the potential for new services (Tomazzoli et al.2023).

This study suggests that artificial intelligence can be utilized in designing new or existing product experiences through an "experience abstraction technique." The goal is to develop generic customer and consumer objectives beyond the product concept and define additional experience settings. The theoretical model is based on designing product experiences related to consumer behavior in physical situations and cognitive product experiences. As the product experience level moves from physical sensorimotor to higher cognitive levels, artificial intelligence will contribute to smarter design. This suggests that AI and emerging technologies are needed to achieve incredible user experiences and increase the list of preferred products in a consumption-focused world.

1.2. Research Scope

The study is structured with the following scope in mind: How could AI contribute to the experience design of physical products?

1.3. Research Objectives

In summary, this paper aims to:

1) Understand the state of the art of technological evolution for enhancing experience design of physical products
2) Evaluate the adoption of AI technologies in enhancing experience design, and
3) Highlight the research challenges and potentials within experience design to enhance customer experience and emotion.
4) redesign user experiences in physical products and services by integrating AI into physical product and service design.

This integrative approach addresses concerns related to AI ethics and empowers AI applications in human-centered applications. It combines different design disciplines, focusing on user-centered design.

1.4. Methodology:

The paper uses a literature review and empirical field study to address these concerns, demonstrating the potential of AI in enhancing product and service design

Under the umbrella of experience design, three

subfields during the timeline of the technology revolution, including UX, product aesthetics, and smart products, are explored in this research. The analysis is conducted using the data extracted from various sources, whereas the state of the technology across various periods is then compared in light of the extensive and comprehensive literature review.

1.5. The research questions

These research questions aim to help us understand better how AI can contribute to the experience of physical products and the experience design of product and service development. Additionally, the questions seek to identify several areas of methodological contribution to academia and practice because of the challenges addressed by the research questions. The research questions follow as such:

1) How does the state of the art of AI technologies enhance experience design practice?
2) What are the solutions to overcome these challenges through enhancing the experience design of physical products to enhance customer experience and emotion?
3) What is the experiential approach and the experience design of physical products and services?
4) What is the role of AI in designing experiences for products and services and creating human-center d AI applications?
5) Which methodological contributions could experience design offer, and how can this field be further developed for academia and industry regarding integrating AI into product and service design?

Finally, incorporating answers to the above-mentioned research questions, the research methodology of advancement and challenges filled by AI technologies will be presented to conclude with future research directions.

2. Foundations of Experience Design

A product can be viewed from two perspectives: its sensory attributes and the experience derived from its use and ownership. The first perspective focuses on the product's functional, emotional, and social properties at the micro level, while the second perspective focuses on the macro-level properties that represent subjective user perceptions and behaviors. The overall user experience drives consumer satisfaction, loyalty, and advocacy, and a great experience can overcome small functional defects. Physical product experiences, including usage and aesthetics, are associated with sensory marketing stimuli and are recognized in the fashion design field as a significant criterion for creating value for the user. (Vidili2021).

Product design is a crucial aspect of the total user experience, affecting immersive events, services, and single encounters. It involves intentionally creating physical products that users are drawn to upon first exposure, feel satisfied with after use, and are proud to own or use repeatedly. Industrial design and engineering professionals use their expertise to innovate and create endearing products like cars, smartphones, and fashion apparel. Progress has been made in experience design and human-product interaction to understand the relationships among factors associated with pleasing and enduring user experiences of physical products (Berni et al., 2023).

XD is the practice of designing products, processes, services, events, and environments with a focus placed on the quality of the user experience, and accordingly, on the experiential value of the product as it is used. This field emphasizes making what a consumer does with a product meaningful, thereby providing utility in the experience of using the product. XD spans and intertwines with many other concepts such as user experience (UX), human-computer interaction (HCI), customer experience (CX), and cultural and emotional design. Among these various considerations, however, psychological, sensorial, emotional, and hedonic considerations have received the greatest attention, perhaps due to the tangible benefit offered by such experiences in consumer-facing applications by guiding user interaction and adding value in terms of pleasure or engagement (Kanungo, 2022).

Experience design is an interdisciplinary field that involves understanding how people engage with products and services, and using that understanding to guide design, marketing, and business strategy. Understanding what and why a person does something helps unearth insights that can be used in creating unobtrusive and meaningful experiences with the ultimate goal of growing a product or service. Products designed from these understandings are better received and enjoyed by the users. Products designed with user emotions in mind have reported increased usability, recommendation, attachment, trust, advocacy, and loyalty. Measuring emotional responses is a complex and challenging task, and every reported approach has its unique set of complexities and problems (Yusa et al.2023).

2.1. Elements of Experience Design

Physical products differ in terms of size, shape, weight, material, structure, colour, surface properties, pattern, etc. We focus on aesthetic experience design, defined as the delivery of pleasing and/or inspiring aesthetic experiences when engaging with these physical products. Perfect aesthetic experiences can cultivate a state of self-forgetting, yet there is no general formula for designing them due to diverse individual perceptions and varied product characteristics. Emotional expression is the essence of aesthetic design with the most significant market impacts.

Essentially, emotional expressions use colour, form, line, impedance, direction, and texture to represent other aspects of a product. They communicate different performances, functions, or symbolism achieved. Emotional expression is different from the basic properties of material, form, and colour that support it; we will consider these two sub-dimensions separately (Hou, 2020).

The expression dimension uses aesthetic elements to represent the desirable expressiveness attributes to be communicated through customer and market segmentation, target reactions, and design brief interpretation. We define the expression into 11 types, including active, passive, response, cold colour, warm ethos, etc. We extend product representation from association to physical and personality attributes to anticipate potentially surprising reactions and bridge new marketing opportunities. These innovative aesthetic design properties are then applied to enhance user experiences (Bruns et al.2021).

Defining the term experience design might be challenging. Experience design relates to the process of trying. It is both about things that are. The result of experience design is a meaningful user experience. Four essences of UX could also be assumed as critical elements of ED: including hedonic qualities of a product, such as fun, pleasure, and arousal; engagement; emotional design; and the meaning of a product, such as subject-object relationship and individuality. Three levels of user experience design include visceral, behavioural, and reflective levels. Based on the abovementioned literature, a comprehensive definition of experience design would encompass four different facets: the hedonic aspects of interaction, the emotional elements, the level of behavioural engagement in a task, and the reflection on the design in terms of an object-subject relationship (Javaid et al.2022).

Engagement refers to the level of involvement with a product and its usage, influenced by the user's efforts and usage situation. Emotional design involves emotional experiences arising from direct interaction with the product, which are subjective and unique to each user. Experience design relates objects or systems to their environment, with the context of a user influencing the design and tools used. Designing an experience involves designing the product, the mover, and the physical or social context. The user-centered and user-experience design methods consider the user's needs. (Algharabat et al.2020).

The primary components of what defines good experience design have been established. Usability, aesthetics, experience, economics, hedonic quality, and fun and playfulness are instrumental in the realm of experience design methodologies. The five elements of experience design, which are usability, economics, functionality, aesthetics, and context, are essential in shaping user experiences. A designer's duty in creating well-crafted products is to keep the user in mind. Users often face difficulties and frustrations with 'user-friendly' products, and although not manipulating, a question is raised on the reliability of a system that is designed. Prototyping is useful for designers to collect user feedback and make a wide range of iterative improvements before the final version is released. The physicality and tangibility of the products have a marked effect on the user experience, and today these experiential elements further enhance the experience slightly more. Finally, the tangible elements alone or the digital experience to enhance the product at this point come into the picture (Lewis and Sauro2021).

2.2. The Evolution of Experience Design in Physical Products

Experience design in the context of physical products has come a long way. Until recently, most designs focused primarily on functional aspects—innovating the working parts or styling the intended visual appearance of the product. Emphasis on function, however, struggled to address obscure user needs. As the technology supporting physical products has matured, the impetus for creating new functionality has lessened. Instead, the focus has shifted toward extending product capabilities and enhancing user experiences. At the same time, gradual social changes in consciousness have emphasized the importance of immaterial values. Consumers increasingly value the experiences derived from a product rather than the product itself. As such, sufficiently integrating these values into a product's design has become paramount (Nunes et al.2021).

Some of the historical approaches to product design—such as design thinking and user-centered design—were born from the need to leverage the experiences of use in the creation of new products. Simultaneously, the products themselves have been digitalized: they increasingly contain electronics and feature typically digital immaterial, such as algorithms, that mediate the experiences users can have with them. In this work, we analyze how to enhance the experiences digital materials offer, and to do this, we look at existing practices of complexity designers (Bu et al.2021).

In the last decade, we have seen the 'digital materialization' of products, i.e., the integration of digital immaterial, such as algorithms, into predominantly physical products. These digital immaterials are designed to offer experiences that almost feel magical or that require almost no intervention from the user, such as an automation algorithm that reduces energy consumption with no need for user input. To capitalize on these opportunities, designers and researchers developed the nascent field of experience design, where the

goal is to transform devices so that the experiences offered by the integration of digital materials are easily understandable and enjoyable for product users. This is important because the seamlessly functioning devices that complexity design sets out to produce significantly alter our uses and behaviour and are often endowed with the same 'user-friendly' qualities (Gray et al.2020).

2.3. Experience Design and AI

This subsection focuses on AI in experience design. AI technologies present various ways to improve communication with users and the overall user experience. For example, AI helps in personalizing the experiences according to each user's behaviour or preference. It can even be extended to changes in the physical layer of services or products where AI helps in generating adaptive designs in real time according to different interacting parties and their interactions. Integrating AI into different fields to work successfully requires closing the knowledge gap and alignment between tools and methodology and between data and action (Ameen et al., 2021).

AI is revolutionizing experience design by providing insights that link functionalities with users' needs. However, challenges remain, such as analyzing large amounts of data and evaluating the practical impact of AI models. Various industries have already integrated AI into experience design, such as physical product design, which has shifted to connect physical products with digital services and apps. AI is taking this layered design of experiences to new levels of personalization and anticipation within digital, physical, and service/product ecosystems. This includes bio-inspired creative exploration and learning experience patterns from Fablabs. (Subramonyam et al.2021).

As the experience economy advances at a rapid pace, adopting traditional user-center d design methods to create unique experiences in physical technology products for users confronts numerous challenges. The goal is to explore the role that AI can play in further enhancing experience design, which aims to utilize innovative emerging digital technologies. In doing so, the aim is to project into the near future to stimulate further research and discussion about utilizing AI in enhancing experience design (bin Ahsan, 2024).

Artificial intelligence is a foundational technology that fills the physical experience design industry with hope and fear. The majority of the hope can be related to AI techniques helping in facilitating classically challenging issues that need to be addressed in a manual style. By investigating the current applications of AI in a selection of industries with an experience-focused user group, certain negative aspects of physical product experience design are evident. It is observed that AI, assisted by deep learning, can improve current experience designs that utilize sensor-generated data from the physical context. Meanwhile, AI can use the information produced by the interactions between users throughout the physical service process to create more unique, personalized experiences (Yuan et al., 2024).

2.4. Integration of AI in Experience Design

The value of AI in design has been outlined by many landmark publications to date. However, the integration of AI tools and AI-generated interventions into workflows has yet to be thoroughly addressed. Recent attempts to incorporate such capabilities in design practices stem from traditional design experience and general research in AI-augmented design, proposing different methodologies for AI's intervention in design. Specifically, some research work in targeted frameworks aims to enhance collaboration between AI experts and experienced designers by taking an experience-led approach to AI, using AI-generated data to enhance service design processes and emphasizing seamless collaboration between actual users and a design team with AI expertise. Many available tools that aim to blend AI capabilities with design practices are being commercialized, mainly for digital product and service domains. In the product domain, an uptake in methods that directly guide form exploration is still lagging, but case studies on how designers worked collaboratively with AI to synthesize and communicate experiences across different scales have been discussed. Notable examples include a focus on the collective involvement of curators, architects, and artists to design one immersive and all-encompassing seamless experience, allowing the use of AI to enter a realm of design 'not only about objects, but also about narrative, dialogue, inclusivity, and the flow of time and space. (Taye, 2023)'

This subsection argues for a user experience-led approach to driving use cases for integrating AI-augmented experiences. This should involve considering how AI may be embedded as an intrinsic constituent, designed for the extent and nature of interaction to inform the design of the semantics and metaphysics layer of the product. The produced method and tool:

a) represents AI as more than a tool;
b) builds on state-of-the-art insights; and
c) provides multiple empowering layers.

Given that this research advocates this particular focus, and this paper has elaborated everything from its origins in terms of approach, the work will advocate for integrating AI into physical product design to augment experience digitally in more

detail (Grech et al., 2023).

Various methods and tools exist to express consumer usage experiences of physical products, but they can be inaccurate and time-consuming. With constantly changing consumer needs, relying solely on human product design teams is inefficient. Consumers often need learning experiences to use new products. Experience design efforts should anticipate various usage contexts of product features, but this is a challenge. Currently, data from interviews, questionnaires, and observations is used to infer user experiences, but this method is inadequate due to its verbal-based nature. (Unger & Chandler, 2023).

By translating experience design outcomes into a format that can be used in AI training, experience design can be made more robust. For instance, concept classifiers can be trained to automate the branding of experience design outputs and, if there are any, to automatically determine feature combinations that had been missed by the designers. Where new use context data is available, data science can resort to present evolved context classifiers, which would help businesses do a better job with recommended written guides or voice-enacted tutorial design. Similarly, by training classifiers on experience design outcomes, touch sensors can be designed more accurately into the body. AI must not simply pump in recommendations based on collective knowledge. Instead, through these tools, incorporate concepts that could be or should have been in the knowledge of designers to start with.

2.5. Tools of Integration of AI in Experience Design

Designers have been using AI for designing tools. AI can be integrated into the tools in different formats and methods. Some of the tools analyze different aspects of the user experience via various AI methods and stake the results, or they provide insights to identify design issues and improvements. In this section, we propose some examples of the tools that are available and used in different domains (Shneiderman, 2020).

AI software companies offer software capabilities as part of Software as a Service, focusing on understanding users to support design creativity and commercial decisions. These platforms are created after research in recent years and can be integrated into design tools throughout the design process. To fully utilize AI capabilities, the design team needs to be educated and understand how to use the tools effectively. AI tools serve designers in multiple ways, including understanding user needs, guiding creative decisions, and facilitating buyer-seller exchanges. (Bawack et al.2021).

We highlight that numerous design software applications on the market describe themselves in terms of an AI-based 'analytic.' These tools are insufficient for helping collaborative design using AI. The tools mentioned are those that offer AI/ML algorithms for tasks such as predicting human responses, collaborating between humans and AI for assets, and so on. Our focus is on providing tools for the design team to use directly, including business designers and analyst roles, not developers. Custom prototyping tools incorporating AI would be more closely related to computer-aided design. However, these software packages do not support sharing AI-recommended designs directly between distributed team members, and they only support design for web-based digital platforms. This is also one of the downsides of using mainstream tools in design practices from a usability perspective. Tools such as those described will enhance creativity and collaboration through design. (Kamrowska-Załuska, 2021)

AI is being used in experience design to enhance direct interactions and create more engaging narratives. This involves utilizing human sciences, materials, and software and hardware to create complex structures and provide heuristic meaning to users. The computational tools used to maximize AI, hardware resources, and software are based on limited research to improve public communication and create a balanced life. The exploration of new features is based on user best practices and cultural and creative requests. (Shneiderman, 2022).

The efficiency of AI has been enhanced by autonomic computing, practical belief measurement, neural network development, and deep learning algorithms. This research explores the relationship between narrative and AI, focusing on mixed methods of qualitative and quantitative experiences. It explores the role of custom speech and natural language interfaces in storyline construction, preferences, and selection tools. The study also examines improvements in chat and persuasive interfaces using semantic techniques, text summaries, and game changes, offering insights into the potential of high-quality devices. (Gkikas and Theodoridis2022).

2.6. Applications of using AI to Enhance Experience Design

Artificial intelligence can be integrated into various stages of the design process. It can also be used through 'interval-level' with less intrusive generating prescriptive suggestions that designers use. In this approach, it integrates into existing design processes by transforming traditional workflows. AI helps establish and accumulate resources as design insights and provides reasons for behaviour across proprietary and open assets.

AI conceals in the back end the capability of a system to change a user's experiences by applying

this information on-site to change the characteristics of the content being displayed to them. Familiar examples are seen in the recommendation systems of various platforms. One of the leading companies that design these sorts of systems with AI techniques is referred to as the pioneer company in the field of A/B testing. Based on a user's past behaviour on a site, top AI companies custom-tailor the interactive features of their platforms or applications. These companies also provide tools to automate the recognition of bad or damaging bugs in an experience after weeks of testing uncertain sets of designs. More recently, AI has been integrated covertly into design tools so that designers can use AI insights to inform their actual creative decisions. In this iteration, AI is coming into its own, as seen in products launched by various companies, which include lists, descriptions, and other features that adapt to the selected products (Armstrong, 2021).

2.7. Advantages of AI-driven design

1. Automation of time-consuming and repetitive design activities
2. Creation of fresh, original design concepts
3. Increased productivity and efficiency during the design process
4. Individualization and adjustment of designs according to use
5. Design optimization with a focus on particular goals or requirements
6. Data-driven insights to support well-informed choices
7. Encouragement of designers' cooperation and co-creation
8. Constant iterative improvement driven by user input
9. Risk reduction by modeling and forecasting design performance
10. Scalability is necessary to successfully manage large-scale design projects.

2.8. AI-driven Personalization

Personalized products are those tailor-mades for an individual to reflect its characteristics and identity. They are frequently regarded as an emotional bond between consumers and products, sharing memories and sentiments with consumers and illustrating a sign of superior taste, individuality, and a unique lifestyle. Personalization has grown so popular that it applies to many industries and different products, nearly pervading our daily lives. Consumers also express a positive attitude toward these products. The degree of personalization, from color, pattern, and texture to markers who are willing to add personal symbols or initials to composition, is usually a personal choice. Since they are tailor-made to meet the palatable desires of different consumers, a significantly fine margin is earned in this kind of product, and personalization normally stands for an increased premium of mass customization (Urban et al.2022).

Although personalization broadens the satisfaction of consumers with products, the strategies or practices of personalization remain fixed and passive, and can't cater to the increasing desire for personalized products. Generally, designers stage solutions or proposals before consumers, and according to these, consumers make personal adjustments. The motive of personalization is according to consumers for their own or for gifts to others. Many gifts may be customized to impress gift-receivers. A self or another's personal experience, past or present, by symbol association, may connect the gift and gift-receivers. As numerous purchases are emotionally driven, especially as they relate to gift giving or personal rewards, the recipient's association with the enabling technology may be interesting enough to choose the personal gift. Of course, the best gift is one that is emotionally rewarding to the receiver, can meaningfully represent the associated memory, and becomes part of the daily life of the receiver (Dahlgren et al.2021).

AI-driven personalization is considered the essence of designing products and services for maximum user satisfaction, as it is about creating a unique and innovative experience for each user. Personalization of product interactions is about managing user demand and supply. Personalization algorithms can leverage AI techniques better than human-developed personalized systems, as they are capable of learning and improving user interaction with the product while the user uses it. This system adapts the response to a user based on a profile of the user, including the user's likes and dislikes. To truly personalize, a proactive personalization system would need to know in advance not only preferences and dislikes but also the factors affecting the user (Hashemi & Bosnjak, 2024).

AI-driven personalization uses many methods to segment users, including clustering and other AI techniques. Personalization is generally clustered into four different methods for providing a tailored interaction: collaborative filtering, content-based, knowledge-based, and hybrid recommendation. The difference between these methods lies in how the personalization algorithm creates a model for each user. A personalization solution starts with data on individual behaviour and then uses various AI techniques to create a model that can predict the behaviour of individuals. Personalization models learn from data such that the more data available, the better the model will perform. There are technological, ethical, legal, and social concerns

regarding privacy, security, and equity that deviation from the mean or the median based on which the personalization is performed needs to be taken into consideration. A case study conducted on the personalization of an in-store robot interface in a grocery shop concludes that those participants who were able to personalize their interaction with the shop were significantly more satisfied with the interaction process compared to the control group. This suggests that AI-driven personalization can provide a superior consumer experience when implemented well (Coelho, 2024).

3. Artificial Intelligence in Product Design

Artificial Intelligence (AI) has been applied in design to reduce design time, improve quality, and reduce design failure. The development of AI has been categorized into four main eras: expert systems, connectionism, cognitive architectures, and deep learning. Expert systems, which were rule-based problem-solving systems, dominated the field of predictions and diagnoses but are no longer the most powerful algorithms. Connectionism, which began in the late 1980s, introduced neural networks that learned from experience to design problems. However, this approach had limitations due to its inability to handle real-life problems. Cognitive architectures emerged in the late 1980s, aiming to replicate the mechanisms of cognition that enable human performance in various problem classes. LIDA-based systems were notable for their ability to model concept formation and learn new concepts in a limited time. Deep learning, the latest era, is based on neural networks but has many layers of processing and can efficiently process large amounts of data. (Lu & Zhou, 2021).

3.1. Fundamentals of Artificial Intelligence in Product Design

The integration of artificial intelligence (AI) and machine learning (ML) technologies within the design process and lifecycle of a product is a concrete matter of research. Within this work, a step further in the utilization of these technologies consists of the quality of design projects for the development of innovative products and experiences. Also, the growing presence and interest in this approach pose the issue of how these technologies can take advantage of modern tools to enhance the overall design outcome of physical products in terms of customer attitudes and behavioural actions and experiences. Often, AI tools optimize well-defined tasks. They are systems based on data and mathematical rules that underpin the operation of the various tools available on the market (Wang et al., 2023).

AI technologies are designed for specific design tasks, with supervised and unsupervised learning technologies being the most common. Supervised ML technology predicts the outcome of a new response based on predictor variables. This process is referred to as predictive modelling, predictive analytics, machine learning, and predictive data mining. Most AI tools in the market are supervised learning, but unsupervised learning technologies are also being developed. AI tools help designers collect, analyze, and understand consumer attitudes and behaviors, enabling the creation of successful, next-generation innovative products. (Haleem et al.2022).

There are many AI-based techniques for enhancing product design. We shall use the product design cycle presented to represent how AI is integrated into this field. AI techniques are used in different phases of the product design cycle, starting from identifying customer needs and defining design specifications to finalizing a design, implementing it, and supporting it when in use. AI is used in almost all phases of the product design cycle, such as recognition, learning, reasoning, and decision-making. These different techniques are used in the five phases of the product design cycle (Lo et al., 2021).

AI techniques can be used to recognize customer needs and preferences. They can be used for learning and reasoning with available data, facts, and expertise in transferring, reusing, sharing, and integrating design knowledge to assist in design decision-making, which includes making decisions about the choice of concept, architecture, market of a product, selection of materials used in its manufacture, and maintenance during its operation. AI techniques are also used in defining the design layout and geometry, the part geometry and specifications, and the assembly process. During concept design, optimization methods are used to find the best, or at least the right, solution, and AI is used to reason about them. The manufacturing phase is performed through robotic machinery, and the product should be assembled and tested with the help of AI to a certain level of quality assurance (Zhai et al.2021).

While AI has been widely used in computer-aided design, manufacturing, engineering, construction, architecture, and music composition, very few studies have been identified that empirically explain the impact of AI or AI-generated design on product experience. Designers and computer scientists with expertise in AI can employ machine learning, data analytics, or analysis techniques to derive insights from data provided during or after the use of products. Customer path analysis was used to analyze an individual's use of an interface product in a product service system more efficiently and come up with better ways to tailor the interface. AI was also used to identify commonly used features and targets to support and encourage

engineers to think creatively when designing new products. Furthermore, data from product use can be analyzed to help stakeholders identify gaps in the user experience and thereby discover new product concepts that would enhance the overall experience in a specific area of interest that is important to users. AI-based technology was also developed to support the innovation process based on the output of computational needs assessment. Thus, AI can optimize designs to be aligned with the physical requirements and the desirability of products. By knowing AI, professional designers can use it to predict technological advances, discover sources of innovation, choose the best solutions based on big data and analytics, and specify design requirements appropriate for incorporating advanced technologies. A front-of-package product designer may use AI to discover patterns among existing products within a product category, helping designers and firms avoid lawsuits. Collaboration between AI and voice recognition professionals has previously generated new value propositions for new design approaches. Moreover, an important collaboration between engineering, product design, and AI supports design research (Ameen et al., 2021).

3.2. How can Artificial Intelligence benefit Product Design

AI has the potential to significantly improve the design process, from early concept design to factory planning. It can be used to generate and develop ideas, schedule manufacturing resources, and improve design proposals, prototyping, and testing. AI has been applied in supporting modern product design activities, such as rapid brainstorming and sampling new designs for diverse product design and CAD. The creation of real products using AI, trained on large datasets of popular goods, allows for quick and efficient validation of the correct design of new items. AI can also function as a common instrument for concept-planning objectives, delivering revolutionary technologies in restorative tissue modification and problem-solving systems. However, the best ways AI could enhance concept design have not been addressed or studied. Successful AI technology integrations include the AI Technology for Innovation Design focus (AIDA program), gas turbine component design, and energy-efficient building design. The implementation of AI results in measurable improvements that can benefit organizations, such as increased user engagement and reduced customer service response times. Overall, AI has the potential to significantly enhance the design process and contribute to innovation in product design. (Verganti et al.2020).

4. Case Studies of AI-Enhanced Product Design

We would like to introduce two examples to illustrate the possible ways in which ambient intelligence can be integrated with physical products to amplify the experience design. Two products of shared use, aimed at enhancing users' sensory enjoyment directly related to cognitive and emotional states, have been studied in the context of an initiative aimed at conceiving programming inputs for the integration of health and well-being features within personal devices to elicit the attention of product design (Dunne et al., 2021).

The "Gourmet gadget," part of an eatery featuring dining with plates and cutlery that provide taste-as-a-service and can customize the taste preferences of the food with an app, makes it possible for customers to enjoy personalized musical calmness sounds before and after eating that shape the food-wellness experience. The "Relax Integrator" is a cushion with built-in bone conduction speakers to reduce stress by inviting the owner to relax with music without discomfort for others, while the cushion becomes a personal regenerating microenvironment for concentration within the intense sound background the owner may immerse themselves into work, whether at the office, in a meeting, or shared spaces. Such examples introduce digital well-being in ubiquitous objects and illustrate new ways to revitalize products with smart rethinking. We believe they can offer thoughts and inspiration regarding the constraints, potentials, and challenges design researchers have to face and engage with when rethinking smart everyday life products (Burr et al., 2020).

4.1. Successful Implementation of AI in Product Design

AI has the potential to significantly influence product design innovation. Successful AI integrations include the AIDA program, which uses AI technology to design vehicles and generate multiple t-shirt designs. Other examples include gas turbine component design and energy-efficient building design. These AI implementations often lead to measurable improvements, such as increased user engagement and reduced customer service response times. Examples include the AIDA program, which uses AI to enhance product performance, and the AIDA program, which optimizes data center interaction in building. (Lee & Trim, 2022).

An organization has successfully implemented AI algorithms in neonatal physiological monitors, predicting complications and optimizing data center interaction. This has influenced the decision-making of the organization to tender for a follow-on project aimed at using deep learning AI to optimize building thermal and electrical systems. AI is used in large organizations with a creative design process, balancing creativity and data-driven decision-making. These organizations use AI to

speed up the design process while maintaining creativity. The emphasis is on the sustainability of AI, ensuring it is continuously improved using steady-state learning. AI should not only be used once, but continuously improve solutions using steady-state learning. (Wamba-Taguimdje et al.2020).

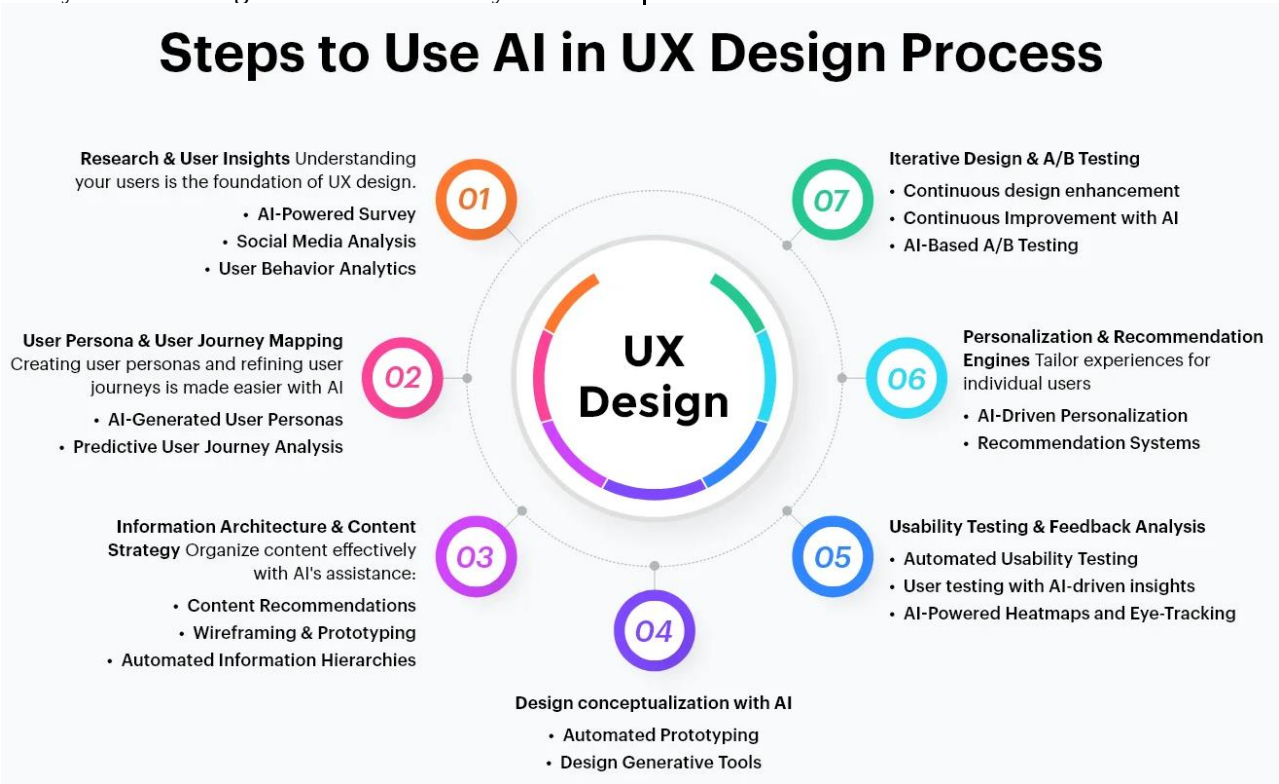

Figure 1 Steps to use AI in UX Design Process

This paper highlights the importance of human factors in using AI to enhance product design outcomes and increase customer satisfaction. It explores how product engineers, industrial and physical designers, and customer experience professionals can influence complex interactions and functional relationships. The paper concludes with a research agenda to identify profitable AI applications and manufacturer viewpoints on engineering desired customer behavioral outcomes. As physical products become more complex and sophisticated, the role of innovative product design is changing. Manufacturers want designs that retain unique features, provide high user satisfaction, and accelerate the relative percentage of costs claimed by software and hardware. Human-generated product interactions and quality of use are crucial elements of risk for successful development and product life cycle value. (Cascini et al. 2020).

4.2. Steps to use AI in UX Design Process

The use of AI in the UX design process involves various stages, and it can assist in each stage of the strategy:

1. **Research & User Insights:** Understanding users is crucial in UX design. AI can assist in this by conducting AI-powered surveys, analyzing social media sentiment, and observing user behavior. These tools can quickly understand user preferences and preferences, guiding design decisions. Additionally, AI can analyze social media sentiment to understand user sentiment and preferences, enabling better design. Furthermore, AI tools can track user interactions, identifying areas of struggle or time spent on specific tasks.
2. **User Persona & User Journey Mapping:** AI can be used to create user personas and user journey mapping, allowing businesses to understand their users better. AI-generated personas can be created automatically, saving time and keeping them up-to-date. Additionally, AI can predict users' navigation patterns, enhancing the overall user experience.
3. **Information Architecture & Content Strategy:** The stage of Information Architecture & Content Strategy involves organizing content and making it easy to find. AI can provide content recommendations based on user preferences, resembling a personal tour guide in a museum. Additionally, AI can structure information in a logical manner, ensuring users can easily find what they need without getting lost.
4. **Wireframing & Prototyping:** AI can

expedite wireframing and prototyping by creating prototype designs based on user ideas and guidelines. This process is similar to having a design assistant, creating various design options for users to choose from, resembling an art assistant painting in various styles.

5. **Usability Testing & Feedback Analysis:** AI can assist in usability testing and feedback analysis by automating user interactions and providing AI-powered heatmaps and eye-tracking. These tools can speed up testing by identifying areas of improvement, providing an X-ray vision of user behavior, thereby enhancing the overall usability of a design.
6. **Personalization & Recommendation Engines:** AI can enhance personalization and recommendation engines by adjusting user experiences based on past interactions. This creates a personalized shopping experience, similar to a personal shopper. AI also helps in recommendation systems, like Netflix's recommendation of movies, allowing users to choose their preferred genres, resembling a movie buddy.
7. **Iterative Design & A/B Testing:** This is where you keep making your design better. AI can be a great helper. AI can significantly enhance iterative design and A/B testing by testing different designs with real users and making adjustments on the fly. This approach is akin to a magician's hat full of tricks. AI also provides continuous improvement by analyzing the UX design strategy and providing suggestions for improvement, akin to a coach helping improve a game.

4.3 Benefits of Using Generative AI in UX Design

- **Fueling Creativity**
  Gen AI can be used to fuel creativity by helping designers explore new ideas and possibilities.
- **Streamlining Design Process**
  Gen AI allows designers to iterate and experiment more quickly. It helps the designer to reduce the amount of manual effort required.
- **Hyper-Personalization**
  Gen AI can be used to create personalized recommendations, content, and experiences that are tailored to each individual user.
- **Focus on Problem-solving**
  Designers can focus more on higher-level strategic decisions and creative problem-solving, ultimately leading to more innovation.

4.4 AI-enhanced UX for Physical Product Design Process:

The design cycle uses AI to optimize customer interactions and create engaging experiences. It follows five stages: Research, Empathize, Create, Test, and Develop, each enhancing customer insights, streamline prototyping, and improving the final product, focusing on user-centered design.

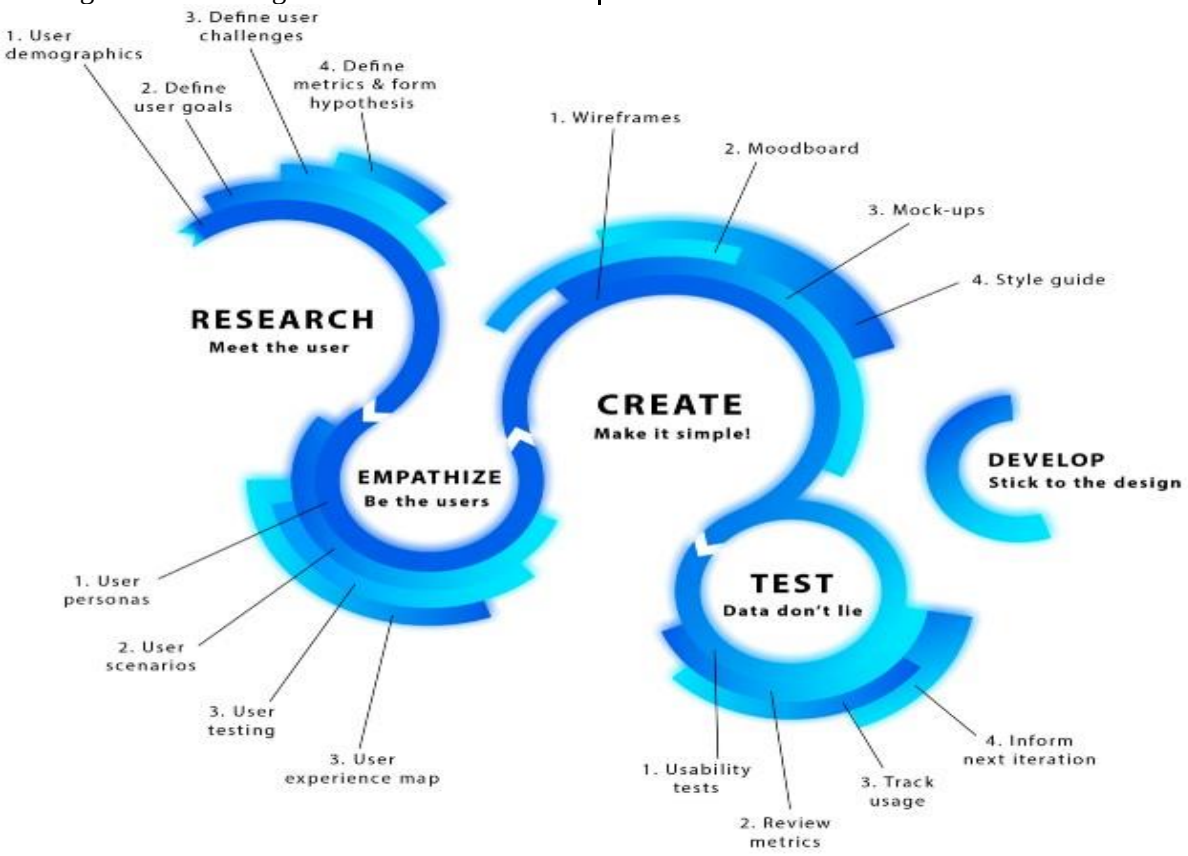

Figure 2 AI / UX Physical Product design Process

1. **Research (Meet the User):**
   - **AI's Role**: AI can assist in gathering and analyzing large datasets about user demographics, behaviors, and goals. Machine learning algorithms might be used to identify patterns in user challenges, leading to better insights into what user's need from a product.
   - **Steps Involved**:
     - User demographics and goals are analyzed with the help of AI-powered tools, which can segment users based on various characteristics.
     - AI-driven predictive analytics might help define user challenges and suggest initial hypotheses based on existing data.
2. **Empathize (Be the Users):**
   - **AI's Role**: AI can simulate user behavior through predictive modeling, helping designers understand potential user scenarios and testing environments. AI-based persona generation can be used to create dynamic, data-driven personas that adjust over time.
   - **Steps Involved**:
     - AI can create personas and scenarios based on real-time data, allowing for a deeper understanding of diverse user types.
     - AI tools can automate some user testing by simulating interactions, generating an early understanding of user journeys and user experience maps.
3. **Create (Make It Simple):**
   - **AI's Role**: AI can aid in rapid prototyping, generating wireframes, and even creating design assets based on user data. Generative design techniques can create variations of wireframes or mock-ups, helping designers explore multiple options efficiently.
   - **Steps Involved**:
     - AI tools can generate mood boards, style guides, and mock-ups with suggestions for optimizing the design based on user preferences and past interactions.
     - AI can support adaptive style guides that adjust based on evolving user insights, making it easier to maintain consistency.
4. **Test (Data Don't Lie):**
   - **AI's Role**: AI-driven analytics can track real user interactions with prototypes and provide in-depth usability metrics. AI tools can also analyze testing feedback in real time, spotting trends and offering recommendations for iteration.
   - **Steps Involved**:
     - Usability testing with AI allows for faster, data-rich analysis.
     - AI can track user interactions over time, providing metrics and suggesting adjustments for improving usability and engagement.
     - Machine learning can help inform the next iteration by learning from past design performance data.
5. **Develop (Stick to the Design):**
   - **AI's Role**: During development, AI can ensure consistency by automatically checking adherence to the style guide and making suggestions for further refinement. AI-powered QA (Quality Assurance) can identify design inconsistencies or usability issues before release.
   - **Steps Involved**:
     - AI supports the implementation by helping maintain the design guidelines.
     - Continuous feedback loops powered by AI can monitor user feedback after launch, helping designers adapt to real-world usage.

This cycle leverages AI tools in each stage to improve user-centered design for physical products, making the process more efficient, responsive, and aligned with user needs.

5. Challenges and Limitations

As it has been suggested by Nadikattu (2021), the design and development of physical products are highly complex and challenging for humans because of various technological constraints and the level of human expertise and intelligence. Though artificial intelligence is having major impacts on many fields, the AI debate often focuses largely on robots, workplace automation, and what some people perceive as significant threats that AI holds, as opposed to the wide range of positive applications AI advancements are and can be made. Thus, it is essential to emphasize the suitability and distinctiveness of AI in various industries to avoid exaggerated perceptions, fears, and potentially inappropriate applications. This chapter studies these potentials and helps avoid exaggerated perceptions and fears, particularly those that are not necessarily technologically justified. Nevertheless, the field is dynamic. One can find a huge number of what some researchers have termed 'AI Winter' periods in which funding and support for AI have dropped due to lackluster results (Tschang & Almirall, 2021).

To achieve a capability to mimic or rival human expertise is difficult and takes quite some time for researchers and experts to accept. Fears and exaggerated perceptions nonetheless still exist and may still be quite substantial. The challenges in

accomplishing creative product designs range from an insufficient understanding of human preferences to trustingly delegating design tasks to machines. A suitable and compatible framework that encompasses users, manufacturers, and stakeholders in product experiences does not exist. Even if reliable and autonomous design agents are feasible, they should be able to negotiate and agree on such abstract aspects as the user's subjective and emotional preferences and background of individuality because all products are essentially ontological artefacts. This challenge does not at all sound optimistic, particularly when there are existing difficulties in designing 'human-information' or memorizing a seemingly simple expression encountered in the product or when there are permutations of unknown consumption. Likely, such difficulties could be due to the known and much more continuing design possibilities, but design agents should be able to handle relative expressions between knowledge and unknown value judgments (Nagaraj et al.2020).

5.1. Challenges and Opportunities in Implementing AI in Experience Design

This text focuses on the experience design of physical objects and highlights the challenges and opportunities present when combining the latest tools of artificial intelligence with each design step. It articulates what it takes to apply AI and related technologies to tasks connected to designing, creating, and implementing physical products and services, i.e. when trying to enhance those design phases that are largely labelled experience design. It demonstrates that the availability of data and access to the needed technologies pose risks in this field and illustrates how and why that effectiveness depends on human understanding and actions (Quach et al.2022).

Designing products and services that provide valuable experiences and deliver on their promises is as important as satisfying users' functional, emotional, and intellectual needs. The generation of experiences through the use of products and services is typically referred to as experience design and is often connected with the concept of design for experience. As experience design may have a multidisciplinary focus, implementing AI and related technologies in the design phases is not an immediate and straightforward task. While researching the topic, the present paper argues that there are challenges and even dangers for practitioners wanting to exploit the offered opportunities. These challenges do not lie in a lack of accessibility to AI-driven technologies, but rather in poorly understood and unaddressed issues. These challenges are the focus of the remainder of this contribution to the special issue (Mühlroth and Grottke2020).

5.2. Challenges of Developing Experience Design Using AI

There are some distinct challenges surrounding the development of experience design using AI. These challenges are categorized as data-related challenges and technology challenges. In the design process, the main objections are usually the inability to obtain the exact data, the quality of data, and the different data accessibility. The problems that can be encountered in this process are the small number or lack of data, the variety of data, and too much information. Furthermore, one might argue that experience design is about users, and one might not ethically use data related to the users to achieve the outcomes. Therefore, designers may resist using the data available due to ethical issues. There could also be design teams who are contemplating using data but do not have access to it. When AI as a technology is brought into a design workplace, resistance may arise due to the misperception of the different skills and attitudes. Within the design industry, as is true for society, some people take to emerging technology rapidly and are proactive in their adoption. This supports the notion that, while it is feasible for designers to build themselves up and use the resources available in a timely way, those in positions of management will ultimately make the difference. Further, if this is the case, the report emphasizes that designers need to maintain adequate training and continuous learning programs to ensure that this understanding of AI in innovative practice can be sustained. Currently, design and computation are handled as technical subjects, running in parallel with one another. This increases the difficulty of AI as a technical subject and reduces the educational efficiency of AI (Karunarathna et al., 2024).

In shaping customer experiences when developing physical products, experience design uses its clients to visualize their intangible needs. The aim is to establish expressive experiences and, therefore, fasten the customer's loyalty. The ability of AI to identify patterns from past data has the potential to empower it to devise new designs. In effect, integrating AI solutions to understand the needs of different clients is a step further toward developing products that appreciate rather than just meet customer needs. Nevertheless, developing experience design processes using AI is not without challenges. The first challenge is in overcoming the possibility of learning the status quo model that does not perform the function. Experience design is more about creating something new and unique; hence, the ability of AI to discern between the different models in its training set will thus be required. This challenge of AI learning from the status quo is experienced when designing experiences to establish or signify brand identity and thereby create customer loyalty (Benbya et al., 2020).

Since AI solutions utilize training data to perfect their performance, another challenge is the need for businesses to supply sufficient training data for AI to learn about customer experience design leading

to the product. In cases where there is not enough data, or AI is expected to learn on the job, enough computational power will need to be invested so that AI can continue to improve through trial and error in designing experiences that result in product development. The third challenge of AI is that there is a need to keep it updated when new datasets or technologies have evolved, or when appropriate. Nevertheless, these challenges of applying AI to the development of customer experience design processes for physical products remain difficult to negotiate, highlighting the necessity to find an opportunity to automate a niche of AI in such areas of business that have hitherto been unsustainable (Verganti et al.2020).

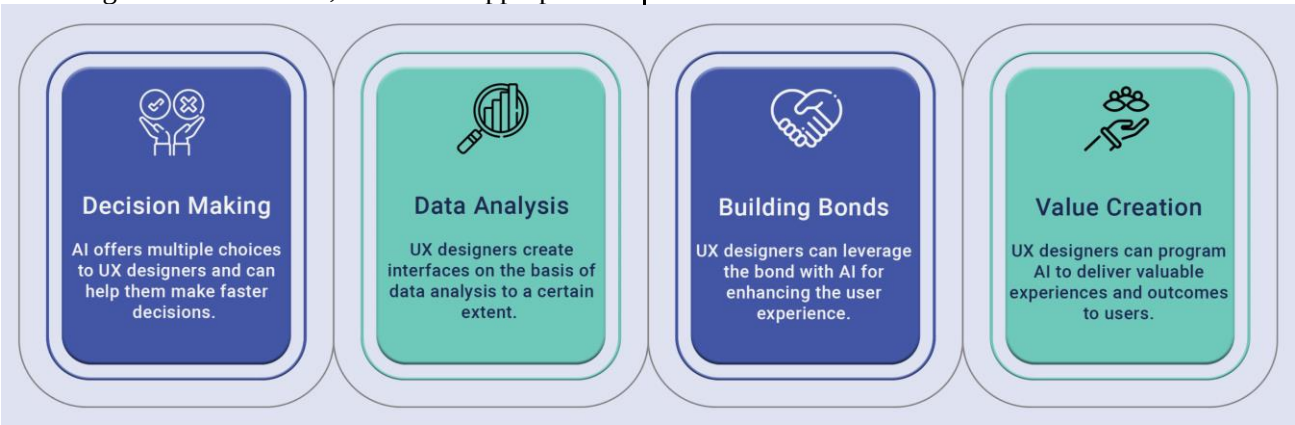

Figure 3 How can AI help Experience Design

5.3 Challenges of Using Generative AI in UX Design

- **Ethical Concerns**
  Gen AI raises ethical concerns. It poses ethical challenges in **bias, privacy, misinformation, discrimination, content ownership, and transparency**. Addressing these concerns requires regulation and responsible use of AI technology.
- **Loss of Human Touch**
  Gen AI could lead to the loss of human touch in UX as designers increasingly rely on AI-generated content. Relying too heavily on AI in creative processes may dilute the human element and authenticity in art and content.
- **Prioritizing Upskilling**
  Designers who are not upskilled in terms of knowing the usage of AI will ultimately be less efficient, and might suffer challenges.
- **Job Displacement**
  Gen AI could impact the role of UX designers as AI-generated content becomes more sophisticated.

6. Ethical Considerations in AI-Enhanced Product Design

6.1. The Ethical Implications

Designing physical products through AI applications raises ethical considerations that digital systems design or AI in digital products often face. Designers have responsibilities when employing AI in the development of physical products or services. Applications of AI have to abide by ethical design standards to ensure user needs are appropriately met and to adhere to national and international regulations or laws. Different themes on ethical design are relevant, including data and privacy, productivity and inclusion, the effect of algorithms, as well as control, moderation, and psychological safety (Sarker, 2022). We see this as a necessary shift from techno-centric thinking towards user-centric thinking. The results of the principles given above form a simple but sufficiently dimensional framework to include in the design process of experience products. It is possible to see the guidelines given above as an exploration into what AI can do, and the ethical standards based on the user's perspective as to how AI can be implemented.

Figure 4 Challenges and Ethical Considerations

We have identified areas that require exploration to understand the long-term effects of AI applications in experience design, namely user engagement, employee satisfaction and well-being, safety, trust, regulation, customer experience, life cycle

touchpoints, and design processes. We want to encourage the introduction of these ethical dimensions in discussions together with technology and user experience experts. To help shape these conversations, we present three AI cases with their respective dilemmas that show ethical considerations of AI in a product development setting on different aspects discussed (Díaz-Rodríguez et al.2023).

While AI is a fantastic companion in UX design, it's not without its challenges:

1. **Fairness and Bias:** AI can learn from biased data and make unfair decisions. It's like learning from a teacher who teaches the wrong things. Hence, you should be cautious while choosing these biases.
2. **Privacy Concerns:** While using artificial design in UX and UI design, AI can collect a lot of data about users. This is why, companies should follow strict protocols to protect the privacy of people. Artificial Intelligence (AI) can gather a great deal of user data through artificial design in UX and UI. AI is able to make unjust conclusions by learning from skewed data. As such, you must exercise caution in selecting these biases. Therefore, in order to safeguard people's privacy, businesses must adhere to stringent policies.
3. **Transparency and Accountability:** Sometimes, AI decisions can be a bit like magic – we're not sure how they happened. We need to make AI explain its decisions, so it's not a mysterious black box.
4. **Responsibility and openness:** AI judgments can occasionally resemble magic in that we're not quite clear how they came to be. In order to avoid the AI being a mysterious black box, we need it to explain its decisions.

In addition to this, artificial intelligence in UX and UI design process comes with several advancements now. It will continue to be embraced in the future too.

6.2. Addressing ethical implications and the importance of diversity.

AI can optimize user experiences through audio-visual means or strategic narratives, but its ethical implications can generate cultural strife if not monitored. AI failures before 2018 can be attributed to datasets being trained on predominantly Western sources and underrepresentation of minority groups. Attention is needed to ensure machine learning enables diversity and does not reproduce or perpetuate biases. AI capabilities are being modelled on nature but also explicitly bypass ethical concerns, relying on current technology's limitations. Addressing personal data and privacy issues is crucial to prevent irreparable damage in experience design. Stories for AI instructors aim to offer resilience against nudge events and encourage the rapid evolution of AI decision-making towards a platform that mirrors a wide swath of humanity. Rapid prototyping and deployment present an advantage, as 'good behavior' AI helps achieve collective and individual aspirations sooner. AI should evolve based on the needs, aspirations, moral, and cultural values of the communities it intersects and permeates (Alter, 2020).

7. Future Directions and Opportunities

Artificial intelligence (AI) is rapidly evolving and bringing value to various sectors, but its potential in designing physical products remains largely untapped. To build AI systems capable of authentic innovation, designers must teach them creativity and augment human creativity with traits like morale and wonder. The goal is to develop new categories of intelligent systems capable of creative problem-solving in known domains and defining complex, ill-defined problems and their associated strategies (Dimitriadou & Lanitis, 2023). This would enable designers to create designs with substantial creativity, personalized functionality, manufacturing limitations, and better fulfillment of customer requests. This would allow for faster production of real solutions that effectively meet customer desires. However, these advanced AI design tools should be developed cautiously to maintain the mastering role held by human designers in the product innovation process. Interest in AI co-creating physical products with customers is growing, but current applications require simplicity and aware control due to health, emotional, ethical, and privacy-conscious concerns. (Cooper, 2023).

7.1. Emerging Trends in AI and Experience Design

From the analysis in the preceding sections, it is clear that AI is becoming a critical technology in the development of smart products. The potential benefits that AI can offer in the experience design of physical products, combined with practical ease of development, are accelerating this trend. We now outline key trends in AI and experience design that are currently at the research stage. How these may eventually affect the area of physical product experience design is currently unknown (Liangt al.2021).. However, it will be significant. Among the research areas, we describe trends emerging in soft computing techniques such as fuzzy logic and how they provide for more centralized and

streamlined interaction with products operating in the real world and requesting adaptive habits and behaviours. They open up aspects of experience design that are unexplored by more predictive AI techniques, allowing for engaging, less predictable interactions that can support consumers emotionally and socially, and motivate them to relate to products as social actors, thus broadening the scope of physical product emotional context beyond sensor feedback. They also allow for less prescriptive and dominant overlaps of AI-driven activities, complementing technical optimization with personal and collective experiences, social interaction, and open-ended dialogue with products (Raff et al.2020).

This section presents case studies of products or prototypes designed by companies or individual designers using AI to enhance user experience. In-depth interviews were conducted with each designer to discuss the design process, approach, findings, and role of AI. Data analysis was conducted using interview responses, providing insights into the various ways AI can enhance user experience design and demonstrating its impact. (Yang et al.2020).

The case studies showcase various AI-enhanced design tools, showcasing different approaches to integrating AI into the design process and potential benefits. The tools were tested in real-world design processes and evaluated. Companies and designers were selected through snowball sampling, crowdsourcing, and industry contacts. The case studies did not consider company size or target market, but their design projects had to be client projects or have client approval. (Yin et al., 2021).

7.2. The Future of Experience Design with Artificial Intelligence

The advancements in AI are yet to stop. From AI reasoning approaches in cognitive models to knowledge-aware analytical systems, AI has transformed itself from a rule-based to a cognitive system, often known as deep learning or neural systems, to the recent trending AI approaches related to natural language processing and understanding. With ongoing advances, the impact of AI will influence future experiences, in turn shaping the experience in product-service systems and manufacturing. From face recognition to personal assistant APIs distributed by tech giants, AI has brought people closer than before (Ameen et al., 2021). Further, the integration of human-machine interaction reaches a more intensive relationship with the development of wearables, IoT, and robotic technologies and products, from smart homes to healthcare and military applications. Advanced AI technology is offering new possibilities to provide end-users with deep personalization; for example, direct user inputs are transformed into a design through AI. This information may be utilized to serve the end-user ever closer and advance into adaptive end-user-platform product-service systems (Laato et al.2022). This also comes with challenges where designers, especially today, will learn how to handle the constraints of AI in both design and use. Already, consumer expectations have started to differ from static and pre-fixed experience designs, and it will continually demand an experience exclusive to consumers. In a scenario of AI-integrated experiences, designers will largely focus on creating experiences determined specifically for their users. The users, on the other hand, in such scenarios or design systems, would most likely share a large part of their input into experience design with the aid of their handheld devices and headphone earpieces, raising further challenges in changing the role of design artefacts and their influence on human interactions. This, in turn, creates a scenario that would strengthen the vision about the alienated values of design artefacts, and designers would need to pursue new methods of thinking behind designing new interactions (Larsen, 2023).

8. Conclusion and Key Findings

The study explores the role of artificial intelligence (AI) in the design of physical products, focusing on the Physical Design Cycle. The cycle involves sequential steps using AI tools to create customer experience models. The goal is to expand customer uptake and enhance the value-adding experience. The paper analyzes the underlying principles of experience design guided by XD frameworks and how AI-based technologies enhance or replace these principles. It highlights the critical role of AI in offering new functionalities in products and the influence of multiple AI techniques and applications. The study reveals that the impact of AI on experience design has led to an evolution in user expectations and a shift in the role of designers. It suggests that AI bots will enhance current prototyping methods and provide game-changing insights. The study emphasizes the importance of adapting to new technological and social landscapes while keeping end-users at the center of the conversation and design.This study has also shown that artificial intelligence (AI) has a significant effect in enhancing strategies and methods that experienced designers apply to create attractive and engaging physical products amidst the emergence of intense challenges and increased product complexity. A review of the current and strategic approaches of AI-supported experience design was yielded through face-to-face and email interviews with research and industry experts specializing in experience design, usability, user-center d design, and product development.

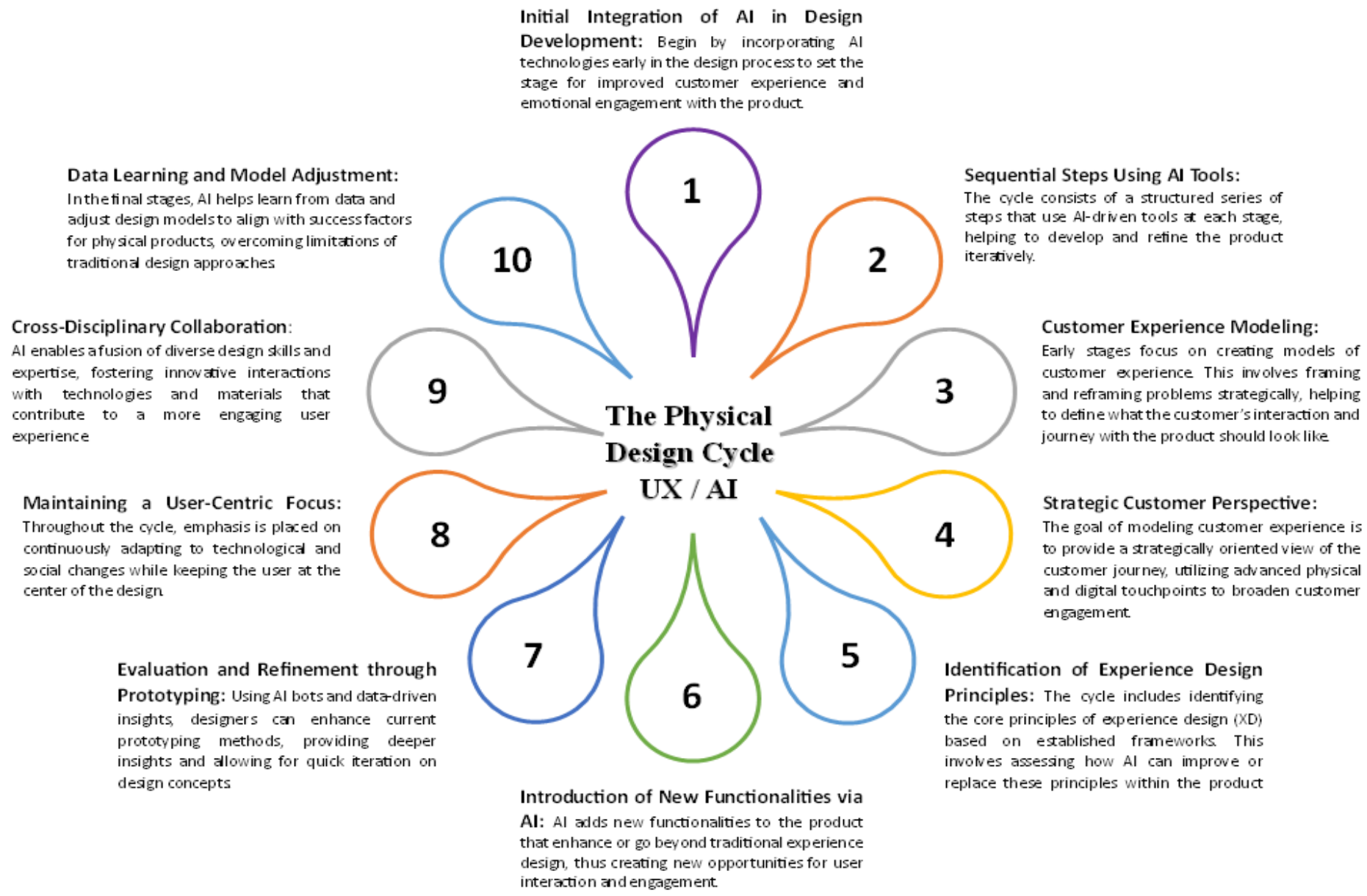

Figure 5 The Physical Design Cycle UX / AI

CITATION Ahmed W. Moustafa et al (2025), The Impact of Artificial Intelligence AI in Enhancing Experience Design of Physical Products, International Design Journal, Vol. 15 No. 1, (January 2025) pp 11-30

Extensive contributions of AI-enabled experience design were advanced alongside the current strategies affecting the exploration of electronic devices, mobile applications, digital entertainment systems, games, website designs, and robotics.

Research and industry experts iterated that AI has not been fully applied in enhancing experience design in any field. AI's contribution to experience design was primarily visible in mobile applications, smart wearable devices, entertainment products, and games. To explore its strength in improving product development and future product concepts covers the recommended future research. Findings from this research acknowledged the understanding that no other product had a self-evolving characteristic that marginally influences its emotional bond with users, but only smart AI-infused products. This study contributes to knowledge in two principal ways: an update was acquired for the AI domain linked to experience design, and a contribution was made that extends the understanding of the potential applications of AI in the experience design field and demonstrates the need to expand exploration.

In conclusion, integrating AI in new phases of the design process helped fulfil the intent of learning from data and modelling the success factors of physical products that the experience design of physical products historically fails to uphold. It also helped overcome the constraints encountered by the many models characterizing physical engagement in the calibration of its models and the manipulation of alternative or competing concepts and their representations to enable machine learning on these models' representative experimental data. As a result, supporting the interaction with transdisciplinary design abilities, technologies, and materials, AI has the potential to have a greater positive impact on design than all previous generations together. However, I am obligated to remind the reader that this preliminary artificial intelligence-supported exploration of selected experientially inspired topics of the experience design of physical products represents a unique subfield among an enormous range of other opened and promising research challenges.

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