Designing Smart Products in The Light of Design Thinking and The Systematic Design Approach

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Smart Products - Smart Product Design - Design Thinking - Systematic Design Approach – Framework.

ABSTRACT:

The research is about how to benefit from design thinking and systematic design approach in
smart product design. The research came as follows:

1. Introduction to the research and included the topic of the research, its importance and methodology, and the problem of the research represented in the multiplicity of Perspectives on the nature of smart products, which led to different methodologies adopted in their design and development. The aim of the research is to develop a framework to take advantage of design thinking and systematic design Approach in smart product design in a way that provides:
- Clear steps for the design and development of the smart product.
- human aspect as a main aspect during all stages of design and development.
- Emphasis on the technical aspects of designing and developing smart products.

2. The theoretical framework of the research, which includes the following topics:
- Smart products, the concept and its relations with other technical concepts, the levels of smart products, the most important characteristics of smart products, the position of the smart product between all type of products, and the enabling technologies of smart products.
- Design thinking, Phases and methods, and its role in solving user-centered problems and its impact on the design and development of smart products.
- The Systematic Design Approach and its various stages, and its role in developing Smart products.

3. the framework, where the research discusses how to benefit from design thinking and the systematic design approach to figure out a framework for smart product design. This integrated framework starts with design task and consists of four main stages, including: research, design, development, and testing. Every stage of them has a main goal and several sub-stages. This sub-stage must be done seriously in some stages and must be done simultaneously in others.

4. Conclusions where the most important findings and recommendations of the research were discussed.

1- Introduction

Seeking for the optimal design methodology is a research goal for many design researchers, there are many methodologies that can be adopted to lead the design and development processes in order to suit the nature of the Products.

Smart products are one of the most exciting Products for research discussions in the field of design studies, due to their special nature that places them in a privileged position in the evolutionary ladder of products. (Mahmoud, 2022).

In this research, we focus on smart products, design thinking and the systematic design approach, and then using the obtained knowledge about these areas to establish a framework for designing smart products that has clear and integrated steps for designing and developing the smart product and integrates the human and technical aspects through all design and development processes.

Smart products are distinguished by their special nature, which makes them in a privileged position, as they are located between responsive products, which are characterized by their high ability to interact with the user, and autonomous Products that are supported by artificial intelligence technology as an enabling technology (Mahmoud, 2022). Smart products are characterized by awareness of the surrounding context, pro-activity, and self-regulation (Mühlhäuser, 2008), in addition to their support for the PLM product life cycle and their ability to adapt (Gutiérrez, 2013), and to create these products, their design and development processes is multidisciplined.

In light of the multiplicity of disciplines based on the development and design of smart products, the perspectives on the nature of these products and their development methods also differ to include many points of view. It allows it to communicate with other smart products in its smart environment in addition to its ability to communicate via the network, (Abramovici and Stark 2013), and there is another point of view told that the smart products are mechatronic products supported by CPS and network communication technologies (Qutb, 2020), The most important thing that distinguishes smart products from mechatronic products is the ability of smart products to communicate with other products in its surrounding environment and its ability to communicate via the network with the user and service providers, but the mechatronic products have limited communication capabilities, which can only communicate with products in its environment (Anderl, Picard , and Albrecht 2013). Smart products include a layer to connect smart products with the service provider (Aitenbichler et al, 2007). Other points of view see that the smart product is another level of products that promise more intuitive interaction and simplicity. (Mühlhäuser, 2008), and many researchers in the field of product design believe that smart product design is essentially woven into the design process, as it is not limited to adding some sensor and communication technologies to the product, but rather that the philosophy of smart products must be permeated within design thoughts during the different phases of design. (Mysen, 2021)

Because of the multiplicity of points of view on the nature of smart products, the perception of the design and development processes for these products also differs accordingly. In short, it is possible to summarize these visions around two main points as follows:

•The first one refers to the smart product as an approach for user-centered design processes, and design thinking is one of the best methodologies that can be relied upon to achieve this aspect.

• The second point refers to the smart product as an output of technical processing of the customer's requirements, so the design process is an approach that has inputs represented in the customer's requirements and outputs represented in the embodiment of the final product, and it is possible to rely on the Systematic Design Approach as a methodology to process this aspect.

The research has already referred to the multiplicity of visions about smart products due to their special nature, which requires the participation of many different disciplines in their design processes, and as a natural response to this, the approaches that can be adopted to achieve these products also differ, and here the research problem is evident, which indicates that there is no framework for designing smart products, with the following advantages:

- Clear phases for the design and development of smart products.
- Posing user as the main focus of the design and development processes during all phases.
- Emphasizing the technical aspects of smart products and providing the necessary vision to achieve these different characteristics during the various phases of design.

The research aims to build up an integrated framework for designing smart products in the light of design thinking as an approach and philosophy for solving user-based problems as the center of the design process, and the Systematic Design Approach

as a method for solving problems associated with systems design.
The research assumes that at a certain level of knowledge about smart products, design thinking and the systematic design approach, a framework can be extrapolated for the design of smart products that has clear phases for the design processes and takes into account the human aspects of the user and the technical characteristics of the product.
The research uses the inductive methodology.
The importance of the research is represented in the need to find a framework for designing smart products in which the usability and technical aspects are integrated during the various phases of design, which contributes to:

- Enhancing the participation of the industrial designer in the design and development of these products.
- Assist organizations involved in the design and development of smart products to determine the proper stages to measure the design and development processes in smart products.
- Helping those interested in studying and developing these products to formulate proper solutions for them.

2- The theoretical framework

The theoretical framework of the study includes three main points:

- Smart products
- Design Thinking
- Systematic design approach

In the following, these three points are discussed.

2-1 - The first axis: smart products

The main value of smart products is reflected in its ability to make decisions, and this feature is mainly related to the autonomousness and self-management. (Hultink, 2003) by looking for the enabling technology of smart product, we find that it is represented in what is called Powerful AI, which is the result of the integration of advanced versions of artificial intelligence. (de Bellis and Johar, 2020)
The intuitive intelligence that supports the smart product, derived from deep learning techniques and artificial neural networks, is what enables the smart product to think creatively and learn effectively from changing environmental contexts and different situations, as well as adapt and take appropriate actions independently (Huang and Rust, 2018).
As a result of the presence of the smart product within a smart environment that includes a group of other smart products, the smart product shares the predictive analytics outputs of pro-active action with other products in its smart context, which enhances their ability to predict events and then improve the pro-active behavior of all smart devices. (Breuker and ET, 2016) (Zheng, Wang & Chen, 2019)
This part of the study aims to form a comprehensive view of what smart products are, in order to benefit from them to induct the required framework. A number of different studies from different fields of knowledge are used to determinate the concept, characteristics and the components of the smart product.

2-1-1 -The concept and characteristics of the smart product

It is difficult to define a specific definition of smart product independently of its environment (Mühlhäuser, 2008). Therefore, it is necessary to define the smart environment before defining the smart product. In this context, the smart environment is that environmental context that is able to acquire knowledge, apply it, and adapt to the existing people. It is used to improve their experience (Das and Cook, 2008), depending on this definition, the smart product is defined as a designated objects to integrate with various smart environments and it is able to self-organize, and provides the user with improved simplicity and openness through its ability to interact with the user (P2U) and its ability to interact with products (P2P) in its environment, and it include contextual awareness, semantic self-description, proactive action, natural interface, AI and machine learning capabilities.
Therefore, the knowledge of the smart product includes three categories: knowledge of the product about itself (including its features, how to use it and its various functions), knowledge of the product about its actual and potential environments (which includes its awareness of other products in its surroundings and how to cooperate and adapt with them), knowledge of the product about its users (User categories and different characteristics for each user). (Mühlhäuser, 2008).
And that knowledge in its three categories is directly related to the interaction of the smart product, which makes it in a state of continuous activity - that is, a continuous update of that knowledge simultaneously with the interaction - it is active knowledge and related to the interaction of the product with the user (P2U) and the interaction of the product with other products (P2P) (Mühlhäuser, 2008). Some have referred to a third type of smart product interactions,

which is the interaction of the product with service providers (P2S), and it is mainly related to smart-connected products (Mahmoud, 2023), but Muhlhauser did not confirm this type of interaction . Smart products are characterized by a set of characteristics that distinguish them from other categories of products, and these characteristics include:

- Environmental Perception: Perceiving situational, environmental and societal contexts and adapting to them.
- Personalization: tailoring products according to the needs of the buyer and consumer.
- Adapting to the user: changing the behavior of the product in response to the behavior and characteristics of the consumer.
- Proactive: anticipate the user's plans and intentions and act accordingly.
- Commercial awareness: Consideration of commercial and legal restrictions.
- Active Communication: The ability to communicate with other products, systems, and environments. (Maass and Varshney, 2008) (Mühlhäuser, 2008) (Gutiérrez and ET, 2013).
- Optimization of performance: maintaining optimal performance in changing circumstances, even in exceptional cases. (Zaeh and Et, 2010)

In general, a smart product can be defined as follows: "A smart product is an independent object designed to integrate and self-organize in different environments during its life cycle, which allows it to interact naturally between the product and the human being. Smart products are able to approach the user pro-actively using sensing capabilities." The input and output of the environment is therefore subjective, situational, context-aware, and can share knowledge and related functions and distribute it among the many intelligent products that emerge over time." (Sabou and Et, 2009).

2-1-2 -Components of the smart product

The smart product consists of three main components:

- Physical components: It includes the electrical and mechanical elements of the smart product, such as actuators and power supply elements. They represent the primary components of the product itself, and these components perform the main function of the smart product.
- Smart components: These include sensors, processing and control media, data storage media, control elements, various software, artificial intelligence software for the product, the operating system embedded in the product and the user interface. These components work to raise the value and efficiency of the physical components of smart products. (Zheng, Wang & Chen, 2019)
- Communication components: It includes the ports, protocols, and wired and wireless communication media of the product, which enable it to communicate with other elements and systems outside its system, (Zheng, Xu and Chen, 2020), and the communication components work to develop the capabilities and value of the smart components of the product and allow some of those Capabilities to exist outside the physical body of the product itself. (Mohelska and Sokolova, 2016)

2-2 -The second point: design thinking

This point aims to identify design thinking, its different models and the most important differences between these models, and to form a comprehensive vision about design thinking, which represents a main step to induct the targeted framework of the research.

2-2-1- The concept of design thinking

By reviewing the literature of design thinking, we find that there are many definitions of design thinking according to the context of the definition, the author's point of view, and his knowledge background. and according to Tim Brown, design thinking is a field that depends on the designer's sense and methods to meet the needs and desires of users within the framework of available technologies and possible business strategies, (Brown. 2008), and Plattner refers to the design thinking approach as a systematic and user-oriented approach to solving real life problems rather than focusing on solving technical problems, where the main focus is on meeting the needs and requirements of the user (Plattner, Meinel & Weinberg. 20) .

on one hand, Lockwood defines design thinking as a human-centered innovation process that emphasizes observation, collaboration, rapid learning, conceptualization of ideas, rapid prototyping, and business analysis. (Lockwood, 2010), on the other hand, Martin emphasizes the element of thinking, defining design thinking as a fruitful combination of analytical thinking and intuitive thinking (Martin, 2010).

Erbeldinger and Ramge, see that design thinking is innovative thinking with a main orientation for the user, and it is based on the principle of multidisciplinary of the work team and connecting

the themes of openness with the need for results (Erbeldinger & Ramge. 2013), and Mootee mentions that Design thinking is a process of searching for a rational balance between business and art, structure and chaos, intuition and logic, concept and implementation, fun and formality, and control and empowerment (Mootee, 2013). A collaborative process based on multidisciplinary team works, which uses a set of different tools and methods, and anyone can apply these processes from seasoned designers and workers in different institutions as well as the most experienced managers and even students in schools (Curedale, 2013). The definition of Ideo indicates, Design thinking revolves around the designer's belief in his ability to make a difference and having a series of specific processes aimed at reaching new relevant solutions to make a positive impact. It gives the designer the ability to be creative and transform difficult design challenges into creative solutions (Ideo, 2012).

In summary, all previous definitions refer to the following aspects:

- The need to set goals: Design thinking aims to develop solutions to current or potential problems.
- User as the center of design process: Design thinking is driven to provide solutions for user needs and problems.
- Iterative stages: Design thinking includes a set of organized and iterative processes to reach the optimal solution.
- Participation of different disciplines: Design thinking relies, in achieving this stage, on work teams consisting of individuals with multiple scientific and professional backgrounds. (Schallmo, Williams & Lang. 2018).

In this context, the design thinking approach can be defined as: it is seeking to develop innovative solutions to existing or expected future problems, and those solutions mainly target the needs and desires of the user. Solutions characterized by complementarity and positive impact.

2-2-2 -Models of Design Thinking

There are many models of design thinking processes (Dorst 2011; Waidelich et al. 2018; Schallmo, Williams & Lang. 2018). Some references mentioned that nearly thirty-five design thinking models were developed over the years from 2008 to 2018, (Waidelich et al. 2018), and as a natural response to the multiplicity of models presented for design thinking, the developers of these models rely on many design tools and methods to explain and clarify the different stages of those models. (Schallmo, Williams & Lang. 2018; Waidelich et al. 2018).

Design thinking models differ in terms of the number of stages and their names within the presented model. Some say that the design thinking model adopts three main steps: inspiration, brainstorming, and implementation (Brown, 2008; Ideo, 2012), and there are those who adopt four stages of their model. Which include: Analyzing the current situation (What is?) Shaping the future, (What if?) Decision making (What wows?) Marketing (What works?) (Liedtka & Ogilvie, 2011), and there are those who present a model that adopts five stages of design thinking: Empathy, Define, Ideate, Prototype, and Test (d.school, 2010), and there are those who adopt six stages of the Design Thinking model. These are Understanding, Observing, Point of View, Ideate, Prototype, and Test (Meinel, Leifer & Plattner. 2011). Some design thinking models reach seven stages, including: Define Design Challenge. Understanding Design Challenge, Defining Perspectives, Gaining Ideas, Developing Prototypes, Testing Prototypes (Schallmo, Williams & Lang. 2018) Even the boundaries of design thinking processes and activities are not agreed upon. Conclusively within the different models: There are design thinking models that start from understanding the nature of the problem from the user's point of view, and end with building an experimental model for the proposed solution, and there are models that include testing and developing the proposed solution within the design thinking activities, and others that include implementing or applying the proposed solution within the design thinking activities The implementation stage is the last stage in their design thinking model. (Waidelich et al. 2018)

Despite this great diversity in design thinking models, all of these models have four basic principles in common:

- Human needs are the first drive of design thinking. People are the source of new ideas, and people are always the center of design.
- Design is a multifaceted activity, as it relies mainly on multidisciplinary teams, and the design team often consists of 4-6 individuals from different disciplines, and each member of the design team is called a Design Thinker.
- Design thinking is an iterative rather than linear methodology. All design thinking models depend on repetition and movement between the different stages in a non-linear, continuous manner to mature and improve the model's outputs.

- Design thinking is an activity that requires a creative environment, characterized by the division of roles and built to promote and develop ideas.

(Brown, 2008; Ideo, 2012; Meinel, Leifer & Plattner. 2011; d.school, 2010; Liedtka & Ogilvie, 2011; Schallmo, Williams & Lang. 2018)

2-3 -The third point: Systematic design Approach

This point aims to identify the Systematic design Approach, its methodology, and its different stages, as a necessary step to form a comprehensive view on what it is, which represents a necessary step to induct the targeted framework of the research.

2- 3 -1 -The concept of Systematic design Approach

The beginnings of systematic design origins before the Second World War, but the formal formulation of the concept took place after the Second World War, and during the sixties, seventies and eighties the concept flourished greatly, and spread widely, especially in the field of designing mechanical and electromechanical products. (Stauffer and Tushar, 2013).

Systematic design is defined as a methodology for developing technical systems and products to meet the needs of society (Pahl and Beitz 2013), or it is a systematic approach to engineering design that includes planning and execution processes to address and implement the fine details of complex designs, and to identify any potential complications of the solution, (ElMaraghy, 2017). In general, there are four main domains associated with design: consumer, functional, material and practical, and the design process focusses on these four domains (Suh 1995).

2-3 -2 -Systematic design Approach

The systematic design Approach includes four main stages: Product Planning, Conceptual Design, Embodiment Design, and Detailed Design. Usually, the boundaries between these stages are not clear, as this Approach often follows continuous repetition and regression between stages when more new information becomes available in a way that contributes to the maturation of the design output (Pahl and Beitz, 2013; Stauffer and Tushar, 2013) There is a lot of iteration between different stages of the systematic design approach.

Systematic design begins with the product planning stage, which aims mainly at formulating design requirements, which can represent design task specified by the client or the organization. Competing products, identifying customer requirements and various constraints in design and production processes, and then writing design requirements.

The product planning stage is followed by the conceptual design stage, where the list of requirements is transformed into an initial conceptual solution. The aim of this stage is to build a functional structure for the product or system to be designed in a way that reflects the requirements identified in the previous stage.

the conceptual design stage is the most difficult stage in the systematic design approach. This stage depends on developing several functional structures that reflect the different aspects of the design requirements, and then choosing the most appropriate one from the point of view of the design requirements. the functional structure of the proposed product/system must explain how power, materials and data are transferred through the product. the functional structure should not present strict commitments of a detailed physical nature to the product or system to be designed.

The embodiment design stage comes after conceptual design stage, in which the conceptual functional structure is developed into a structure that is more specific to the technical characteristics of the final solution. During this stage, various criteria are used to transform the proposed concept into a more embodied and practical solution. During this stage, various parts of the process are addressed. Design and production of the product/system, which includes performance, safety, ergonomics, manufacturing, and other life cycle issues. During that stage, the nature of the product/system crystallizes and its final technical components and characteristics are formed. At that stage, various perceptions and continuous modifications are reviewed directly with customers in order to formulate the final plan. The product/system that reflects the various technical characteristics that meet the requirements of customers.

The detailed design stage comes as the last stage in the systematic design approach, where the design is embodied in reality, and the detailed design discusses the final characteristics of the product such as dimensions, tolerances, identification and selection of materials, performance guarantee, business issues and the expected cost of the design, and executive drawings of the product are prepared, to become the final output For that stage is the final product specification file, including its production manual. (Qutb, 2020; Pahl and Beitz, 2013; Stauffer and Tushar, 2013).

3- The Integrated Framework

Since sixties, the cooperation between different disciplines has been increased, it led to difficulty of cooperation specially in creative fields. Some attributed this difficulty to the different knowledge background of these disciplines, which makes it difficult to find a common language for cooperation on the creative project. The cognitive vocabulary of these disciplines is different, and therefore the language spoken by specialists from these fields necessarily differs, which makes it difficult to collaborate in creative processes (Plattner, Meinel & Weinberg. 2009). Returning to the cognitive background of both design thinking and systemic design, we find that the first stems from The industrial design approaches, while the other is the result of theorizing efforts related to the fields of engineering design to a large extent, and as a treatment for the problem referred to above, it is possible to harmonize both approaches - design thinking and systematic design - through unified framework that covers both approaches and helps to overcome the difficulty associated with the cooperation of different disciplines. in creative processes.

3-1 -Principles of the integrated framework

Design thinking is an approach that relies on the user as the center of the design processes (Schallmo, Williams & Lang. 2018), while systemic design gives greater importance to technical problems (Plattner, Meinel & Weinberg. 2009) for the design solution. Therefore, a set of working principles must be defined to facilitate collaboration between both.

The proposed framework is based on a set of principles that contribute to the formation of this framework. These principles include the following:

- **Integration between design thinking activities and systematic design activities**: The proposed framework for solving problems using design thinking and systematic design relies on a homogeneous and diverse team from different disciplines, which includes members with different knowledge backgrounds from various technical fields (engineers, industrial designers, etc.) and design goals. In order to complete the required design task, emphasis must be placed on the integration and synergy between the various design and development activities.
- **Unity of the design goal**: the knowledge background of the participants in the design project varies, but they are all united by one goal, which is to reach a solution that achieves the goals of the first drive of the project (client or company requirements), which are clearly crystallized during the first meeting with stakeholders (customers with the required task - managers). and employees of the institution proposing the project.
- **Supportive work environment**: The activities of the integrated framework vary, which include design thinking and methodological design activities. In order to reach the best results of these activities with the best possible efficiency, a supportive work environment must be provided for these activities.
- **iterative and non-linear processes**: The integrated framework includes a series of processes, some of them fall within the design thinking processes and others fall under the umbrella of systematic design, and both approaches include a mechanism for iterating, repetition of processes according to the results of each stage. and according to those results, the next step in the chain of operations is determined, whether by advancing forward or going backward, and since both approaches include this property, the merged framework will inherit that property.

3-2 - Integration and contrast within the Integrated framework

After reviewing the literature related to design thinking models and the stages of systematic design Approach, we found that the design thinking model of D.School is the most closely related and compatible in terms of stages, processes and methods with the methodology of systematic design referred to earlier in the research, So it was adopted as a cornerstone for developing the required integration framework. In short, the D.School model includes five basic stages: empathy, define, ideate, prototype and test, and in light of the research's adoption of this model and the stages of systematic design, which included: product planning, conceptual design, embodiment design and detailed design. By comparing both approaches, it was possible to devise four main activities that are common to both approaches. These activities represent the basic stages of integration between design thinking and systematic design approach. These activities include: research, design, development and testing, as these activities are compatible with both approaches as follows:

- Research activities in design thinking fall largely in the stages of empathy and define, while the

stage of product planning in systematic design includes the majority of research activities.

- Most of the design activities in design thinking are in the ideate stage, while most of the design activities are in the conceptual design stage in the systematic design methodology.
- Most of the development activities in design thinking take place in the prototype phase, while most of the development activities in systematic design take place in the embodiment and detailed design phases.
- Testing activities in Design Thinking take place in the testing phase.

Despite the integration of activities to a large extent between both approaches, the center of operations in both approaches differs radically. Design thinking adopts the user as the center of all its activities, while systematic design places the greatest focus on addressing the technical problems of the product, and this difference represents the second part of the essence. Integration between both approaches, and briefly, this integration can be expressed in figure (1)

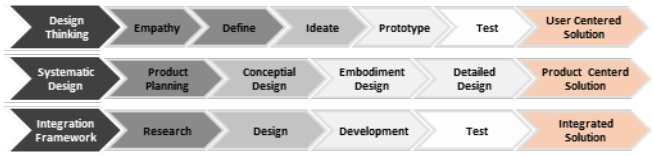

Figure (1) Integration and contrast between the activities and purposes of design thinking and Systematic design within the framework of the proposed merger.

3-2 -The phases of integrated framework

It was previously mentioned that the stages of the systematic design Approach start from the design task that is identified for the design team, which is presented through an interview with the client or an interview with stakeholders from the managers and employees of the organization, and the results of that interview represent a common starting point for all participants from various disciplines, the description of the design task starts the work of the design team, according to the following stages:

- The first stage: the research stage. The main objective of this stage is "writing the design requirements", which represent the cornerstone of the design stage. The research stage includes two partial stages that can be done in parallel:
    - The product research stage aims to study the product or system related to the design task. In the case of novelty of the design idea, similar and related products and systems are studied. This stage depends on the following set of interim procedures:
        - Product/system analysis
        - Analyzing similar products/systems.
        - Competitor analysis
        - Writing product specifications.
    - The user research stage, and the aim of that stage is to form a vision of the design problem from the user's perspective, and that vision depends on its formulation on the following procedures:
        - Explore the problem from the user's perspective.
        - Collect and analyze information about the design problem
        - Arranging and formulating the collected information
        - Formulate the design problem case

  In the light of the results of product and user research, the general requirements of the intended design solution are written.
- The second stage: the design stage. The main objective of this stage is to develop an initial idea for the solution in the form of a functional structure for the product or system to be designed. This stage depends on the following partial stages:
    - Developing a set of preliminary ideas into structure of the product or system. functions
    - Improving ideas by classifying them, deleting similar ones, and merging what can be combined.
    - Choosing the most suitable idea for the organization's resources and the most compatible with the client's requirements.
- The third stage: the development stage, the aim of this stage is to upgrade the initial idea into its final solution closest to the final design output, and to obtain a pilot prototype (fully function prototype) for the product or system that can be tested and evaluated technically during the next stage, and in general it is possible to divide this stage into two partial stages, As follows:
    - Initial development stage: it aims to ensure the validity of the idea decided in the previous stage, so the idea is developed through repetition of two procedures:

- Develop the functionality structure of the system or product.
- Building a model for the product or system.

The prototypes of this stage are often classified as Proof of Concept (POC) prototypes, and PoC prototypes include functional prototypes reflect all the functions of the product and experimental prototypes that reflect only part of the product's functions and it goals to test or verify a specific function in the product, Digital models and simulations can also be adopted at that stage.

- Advanced development stage: The aim of this stage is to reach a pilot that can be tested and verified in the next stage. This stage relies on the same procedures as the initial development stage, with more focusing on raising up the fidelity of the prototypes and reviewing the technical and industrial details.

- Testing and verification stage: The aim of this stage is to ensure that the pilot meets the technical characteristics of the product and the requirements of users. This stage depends on two types of verification procedures:
  - usability testing: to ensure that the pilot matches the user's requirements.
  - Technical testing: to verify that the pilot conforms to the design requirements.

The proposed framework includes four main steps: research, design, development and testing, where each of these stages includes a set of procedures, and it does not necessarily mean taking a linear path for those processes, but rather it follows circular paths to mature the design through repetition of the processes to reach the best possible version of the design solution, and Fig. (2) shows the phases of the integrated framework.

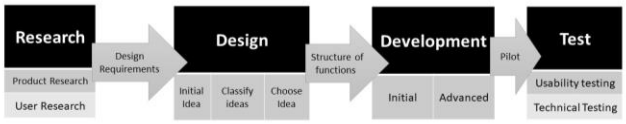

Figure (2) the general framework for integrating the design thinking model of D.School and the systematic design approach.

3-4 -Designing smart products by embedded framework

Depending on the findings of research about what smart products are and their most important characteristics, it is possible to use the integrated framework for designing smart products, where the design task is determined by customer or stakeholders within the industrial enterprise, and these characteristics include the most important features of the product. this step is the starting point for the design processes. This step is followed by the stages of the integrated framework, as follows:

- The research stage, and as we have indicated, this stage aims to define the design requirements, and when applying this framework, the design requirements of the smart product are defined, and those requirements include all the technical and usability characteristics of the smart product, and this stage depends on two steps:
  - Product research, which includes procedures such as analyzing the product and its functions, analyzing similar products, competitor analysis, describing the usage context of the product (the smart product environment), describing the level of the required product, determining the characteristics and technical specifications of the smart product, which include:
    - Smart product level.
    - His environmental awareness.
    - The extent of its customization capacity (how far it can accommodate users with very different needs).
    - The level of intelligence of the product, its ability to adapt to the change in user behavior.
    - His ability to anticipate user behavior and act accordingly.
    - Product awareness of its commercial context.
    - The product is aware of other smart products and systems in its environment and interact with them effectively to improve the responses of the smart environment in general, and other characteristics of the smart product.
  - User research, which includes procedures such as analyzing the patterns of users, personas, their most important characteristics, describing the design problem from their Point of View, identifying the most important needs of users and the reasons for those needs.
- The design stage, at the end of the research stage, the most important characteristics of the smart product to be designed are identified, and this step is the starting point of the design process, and as we mentioned above, the goal of the

design stage is to develop a preliminary structure for the functions of the smart product: this stage depends on three partial stages that take place, as follows:

- Developing the initial ideas for the smart product in form of a set of functions structures for the product (product function diagram). At this stage, ideas can be relied upon such as brainstorming, the SCAMPER method and other ways of creating ideas. The most important thing at this stage is to develop several alternatives to the functions structure.
- Classifying ideas and merging similarities, as the previous steps result in a set of diagrams for smart product functions, which may be similar in some aspects and differ in others, as well as may differentiate in some aspects and integrate in other aspects. In this step, ideas are classified using different classification methods such as the "HOW, WOW, NOW" diagrams, affinity mapping, or other methods for classifying, integrating, and improving ideas.
- Choosing the most proper idea. The previous step provides a set of improved ideas for the functions structure of the smart product. Comparisons are made between them at that stage to choose an idea that reflects the required design specifications. Checklists can be used to achieve this stage.

- The development stage. At the end of the design stage, we have a detailed outline of the functions structure of the smart product. What is required in the development stage is to embody the smart product in form of fully-function Prototype (Pilot) that can be tested technically and in use. To achieve this, the development stage of the smart product depends on two steps as follows:
  - Initial development phase: the aim is to partially develop the design through two procedures:
    - Developing the smart product function's structure.
    - Preparing functional prototypes for the smart product.

The resulting prototypes at that stage are low-fidelity and low-cost models, intended only to prove the validity of the required idea. Most of them are POC, and the idea is developed by several repetition of these procedures.

  - Advanced development stage: it aims to develop a testable pilot prototype, and this stage relies on the same procedures as the previous stage.

- The testing stage, this stage aims to verify the technical and usability aspects of the smart product, and this stage depends on two main types of validations, each of which represents a step in the testing stages, namely:
  - The technical testing of the smart product: in which the resulting pilot is matched with the technical requirements of the smart product, in order to verify the availability of its various technical characteristics.
  - The usability testing: in which the model is tested by a sample of users to verify the ability of the product to comply with the users' requirements, and its ability to adapt and anticipate user behavior and act accordingly.

In both testing phases, all tests are conducted in the same environment or usage context of the smart product, in order to provide a realistic evaluation of the smart product.

4- Conclusions

The research reached a set of results, which included the following:

- The goal of the research was achieved, as it was possible to reach a framework for designing smart products based on design thinking and systematic design.
- The integrated framework is based on four main principles: integration between design thinking activities and systematic design activities, the unity of design objective of the work team, the need to provide a supportive work environment for the various activities of the integrated framework.
- The integration framework includes four main stages, some of them fall within the design thinking activities and others fall within the systematic design approach: These stages include: research, design, development and testing.

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