User-Centered Design in Digital Twins:
Insights Based on Industrial Designers’ Activities

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For the Degree of Master of Science in Innovation and Design

Master's thesis, advanced level, 30 credits
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Velina Parapanova, 2023 Stockholm
Preface

This master's thesis is created in collaboration with the Swedish telecommunication company Ericsson. They provide a broad portfolio range across the mobile network infrastructure. Also, they have a leading role in telecommunication equipment, cloud software and services, and emerging business powered by 5G (Ericsson Annual Report, 2022). The company was founded in 1876 by Lars Magnus Ericsson, a Swedish inventor, and engineer (The History of Ericsson, 2023). Initially, Ericsson focused on producing telephone equipment but quickly expanded its product line. Throughout the 20th century, the business continued to grow and expand its product offerings. The company played an essential role in the development of early telephone systems and the expansion of telephone networks around the world. Later, the focus switched to developing radio technology, and it became the leading supplier of radio equipment for shipping and aviation. Because of the limited Swedish market, Ericsson continued to expand globally and quickly broaden its business with an international market. Over the years the company's position has shifted, its business has changed radically, and on more than a few occasions the company has been close to bankruptcy (Elfving et al., 2015; The History of Ericsson, 2023).

Despite all challenges in the past, today Ericsson has established a strong position and continues to innovate and adapt to the rapidly changing telecommunication market. The company highlights that behind the success in the last years is the solid investment within research and development units across the company (Ericsson, 2023). Today Ericsson is a leading player in developing 5G technology and has expanded its offering to include cloud computing and digital services solutions. Naturally, with quickly increasing cloud technology, there has been growing interest in applying the digital twins' concept in the case of mobile networks as a broad set of use cases, “making it possible to both enhance existing capabilities and introduce entirely new functionality” (Öhlen et al., 2022, p.2).
Glossary

Telco – is an abbreviation of the term "telecommunications company".

5G – refers to the fifth generation of mobile systems, which represents the latest iteration of cellular network technology. 5G networks promise faster download and upload speeds, lower latency, and greater capacity to support more connected devices and applications than previous generations of cellular networks such as 4G, 3G and 2G.

Site types – in the context of telecommunication, refer to different categories of sites based on various main factors such as functionality, capacity, or coverage area. Common types are tower, rooftop, street, and indoor sites.

Type site solution – refers to what solutions and products are included in each of the main categories of site type. Site solutions can include a range of components, such as hardware equipment, site design and planning, construction and installation, and maintenance and management services.

BIM model – BIM abbreviation stands for Building Information Modeling. The BIM model is a tool for designing, constructing, and managing infrastructure projects. It is representing comprehensive project information, including geometric data, spatial relationships, materials, and properties of building components.
Abstract
Digital twin is an emerging technology that enhances digital transformation across many industries and domains. Most digital twins are made for a work context, and end users are the domain experts who carry knowledge in the work processes and products of which digital twin is part. The research gap for the present study is found in the missing adoption of a user-centered design approach and systematic evaluation of digital twins from the perspective of end users. User-Centered Design is a well-known design philosophy that engages users in the design process. By involving users, designers can better understand users and create situations where users can introduce their knowledge, needs and concerns into the products and systems. Emerging research questions for this study are: RQ1: What insights could be obtained with user-centered design and user involvement for the design of digital twin? RQ2: What limitations could user-centered design and user involvement incorporate in the design process of digital twins? This study will use both previous studies and empirical data from a scenario-based approach, workshops, observation, and interviews. Further, it will explore a theoretical framework combining User-Centered Design and Activity theory. This study aims to investigate what knowledge we can gain with users in focus and how that might help to fill the knowledge gap of previous research about user-centered involvement.

Keywords:
digital twin, user-centered design, activity theory, industrial design, scenarios
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Introduction

This section will be comprised of three parts. Firstly, an introduction about this study and what is the current gap related to user involvement in digital twin will be present. After, there will be a section about the problematization, the aim for this study, and the research questions. In the end of the section are the limitations and outline of the thesis.

Digital twin is a rapidly evolving technology that contains physical products in real space, virtual products in virtual space, and links of data and information that connect them (Grieves, 2015). Studies argue that most digital twins are made for a work context where end users are experts in their fields (Nocera et al., 2015; Barricelli & Fogli, 2022). They carry out specific knowledge of the process, products, and services of the organization they are part of. With increasing popularity in recent years, the digital twin is a promising solution in many sectors. At the same time, identifying all possible opportunities and threats can be difficult for designers because digital twins can be used differently by various end users. Involving users in the design process might be helpful and beneficial for digital twins because users can give valuable input that can lead to better adoption of the system (Barricelli & Fogli, 2022).

User-centered design (UCD) is a well-known design philosophy that engages users in the design process. This approach emphasized understanding the user's needs and expectations. Today, there is a missing adoption of the UCD approach and a lack of systematic evaluation of digital twins from the perspective of the end user (Stephanidis et al., 2020, p. 646; Barricelli & Fogli, 2022, p. 12). Users, or as they are called "domain experts", are not necessarily using digital twin yet, but they can contribute to design of digital twin with their knowledge and potential of the use of digital twin. Involving experts in the design process can be essential for workers to "imagine what the future might be like" and understand their work tasks within the new technology (Kuutti, 1995, p. 11). One of the areas where digital twins gained most popularity and are proved be useful is in product design and development (Digital twin market, 2022, Lo et al., 2021; Tao et al., 2018). Industrial designers are one of the domain experts in product design and might be beneficial for the digital twin if involved in the design process. The definition found in the Industrial Design Society of America describes industrial design as a professional practice that focuses on the physical appearance and functionality of products. Industrial designers are involved in stages throughout all the development
cycle (Norman, 2013). In the context of telecommunications, they are specialists in the physical product design of network solutions. Some of their essential tasks are designing and developing hardware components and equipment used in network deployment. Industrial designers test the usability of hardware components to identify and resolve issues that may arise during the development process or after deployment. Also, they research and develop new technologies and techniques to improve the performance and reliability of telecommunications networks. In the era of rapid digitalization, the system and tools used by industrial designers constantly develop. Despite their domain role, industrial designers have yet to be seen today as target users in the digital twin in the context of the telecommunication industry (personal communication, 23-02-08). Therefore, this study will explore this untypical user group to understand better their needs and opportunities when interacting with digital twin. Authors argue “work practices naturally evolve as new technology is introduced” and therefore it is essential to understand how users will adapt to these changes (Rosson & Carroll, 2002, p.60).

With a focus on industrial designers, this study will explore what can we learn from involving users in the design process of digital twin and what can we gain with their domain knowledge and input? Understanding the users’ needs and activity as well as their work context might help create a holistic perspective and help better grasp information on how to develop information technologies (Rosson & Carroll, 2002).

**Problematization, Aim and Research Questions**

Humans are an essential part of any industry and need to be considered when developing digital twins (Singh et al., 2021). By involving experts in the design process, we could make sure that the system meets the needs of the users (Bannon, 1989). More than 50 years ago Gould and Lewis (1983) suggested three principles when designing systems, where the users are a natural part of the development process. The first principle is “focusing on early understanding about users and their tasks” (ibid, p. 300). The second principal authors recommend that target users should test the system to carry out their real work task. This process should be observed, recorded, and analyzed. This is obviously an important step in user-centered development because users can highlight their specific needs in more detail (ibid). The third principle is empirical measurement which helps to test the learnability and usability in the system in its early stage. This should focus on iterative design with users. If any problem is identified in the testing phase, the interested elements should be revised and redesigned to more
user-friendly solution (Gould & Lewis, 1983). In that case, the analysis will be based on the result of qualitative methods and user involvement.

Similarly, Barricelli and Fogli, (2022) argue that it is essential to engage the end users because they are specialists in areas related to the industry in which digital twin is created. With the increasing capabilities of the digital twin and the system's complexity, it also becomes more difficult for designers to identify all user needs and design opportunities. However, today, end users are not always actively part of the design or evaluation of digital twin; nor are human-computer interaction research methods often used (Barricelli & Fogli, 2022). On the other hand, Norman (2005) points out that a user-centered design approach is not always used in the creation of successful technology. He also argues that this approach has become so popular among designers that they use it automatically “without thought, let alone criticism” (ibid, p.14).

Therefore, what emerges in research is the need to explore what we can gain with user-digital twin interaction across all stages from preparing, analyses, design, test to evaluation. Bannon (1989) argues that users have not got a passive nature, but the opposite; they are active agents that want to understand tasks, what is going on, and explore what is ahead. He suggests that every designer “start out with the belief that workers/users are competent practitioners with whom the system designer must collaborate with” (ibid, p.4). This collaboration with users is seen as democratization in organizational change and ensures the system meets users’ requirements (ibid, p.9).

Despite the growing popularity in academia and industry in the digital twin, very little research has been done based on what insights we can bring with user involvement.

This study aims to investigate the role of user-centered design and user involvement in designing digital twin technology. With that, the study might contribute to filling the knowledge gap of previous research about missing user-centered approaches and what could solve the organization and their practical problem of user engagement in the design process of the digital twin. The study aims to explore the following research questions:

RQ1: What insights could be obtained with user-centered design and user involvement for the design of digital twin within the telecommunication industry?

RQ2: What limitations could user-centered design and user involvement incorporate in the design process of digital twin?
The study will investigate the research questions through different qualitative methods such as observation, interviews, and workshops to understand better what users can point out as specific for their working tasks and challenges. Also, in collaboration with industrial designers it will reflect upon what are the possible user scenarios for them.

Limitation
Firstly, this study does not include the technical aspects of digital twins since the thesis focuses on user-centered design and what humans can bring to the development process of the digital twin. Therefore, this study primarily explores the perspective of the users and emphasizes the valuable contributions humans can make to the development process of digital twins, rather than delving into the technical aspects of the system.

Also, due to confidential information and data policy and regulation, the study does not reveal in-depth descriptions, images and visualizations of the Ericsson digital twin portal and the system itself. These measures are implemented to ensure the protection of sensitive information and maintain compliance with relevant data privacy standards. By respecting confidentiality protocols, the study aims to uphold ethical considerations and maintain the trust of stakeholders involved.

Thesis Outline
In the beginning, the study will present the research background, problematization, aim, and research questions, and the limitations and structure of the thesis. After that, the study will look at the previous research to learn in-depth about different aspects of how product design opportunities and challenges in digital twins are defined in literature. The research will follow the user-centered design and activity theory as a theoretical foundation to understand the current situation of industrial designers and their work context with several qualitative methods such as workshops, scenarios, interviews, and observation. Furthermore, the activity theory and activity triangle models will guide the process of the study, including findings and research analysis in the end. Exploring that, we might gain a better knowledge of what a user-centered approach and user involvement can bring to the process and what the possible limitations could be as well. The discussion and conclusion of the thesis will be presented in the end, which will try to reflect on the research question and aim of the
study. Finally, other perspectives and suggestions for the next research will be presented in future studies.
Previous Research

This section will present the previous research and will begin with the key ideas of the digital twin. Next it will be followed by literature classification with highlighted main steps in the process. Thirdly, there will be the final selection of papers and different defined categories and challenges in product design. Finally, a summary of previous research will be present in the end of the section.

Digital Twin – Key Ideas

Grieves (2015) first introduced the term Digital Twin in his work for NASA "Virtually Perfect: Driving Innovative and Lean Products through Product Lifecycle Management" (ibid, p. 133). Later in 2003, the concept of Digital twin model is presented by Grieves at his University of Michigan Executive Course on Product Lifecycle Management. Today, the definition of a digital twin expands and varies areas depending on the context in which it is used. However, in general, digital twin can be thought of as a virtual model or representation of a physical object or system, with the ability to simulate, monitor, and optimize its behavior in real-time. Grieves argues that digital twin capabilities support the “most powerful tools in the human knowledge tool kit” and they are the foundation of the new era form of problem solving and innovation (ibid, p. 4). In his paper the author (ibid) defines conceptualization as a first use case of digital twin. He argues that people process information differently from computers. Humans take the data related to work they are interested in and then conceptualize the situation with their own mind’s perception. They use their visual sight to understand the data. The digital twin can directly take and interpret the information and eliminates the unnecessary mental steps (ibid, p.4). Comparison is another high-level use case that is related to digital twins. Through the twin system we can build a joint view and see both the physical and virtual product information, simultaneously and instantly access information about the physical products. Also, with digital twin technology, we can test ideas and see the ideal combination of what we want to achieve. Thirdly, the collaboration of digital twin refers to the capability of looking at any physical products regardless of the geographical location. Collaboration can happen at the same time between a lot of individuals that are not at the same location (ibid).

Today digital twin technology is used across different industries including construction, manufacturing, aerospace, agriculture, mining, retail, healthcare, military, automotive and public safety sectors. The impact of digital twin expanded across
different use cases (Attaran & Celik, 2023). Authors (Singh et al., 2021) point out a few main areas of implementation of digital twin such as “designing/planning, optimization, maintenance, safety, decision making, remote access, and training” (p.1).

Literature Classification

During literature classification, different research gaps in papers are identified in the review section. One of these gaps is the lack of human involvement and understanding regarding what the domain experts can bring to design process of digital twin. The focus area of the research is product design opportunities and challenges in digital twins. The primary methodology for the literature review is structured into three steps: literature collection, screening, and classification (see Figure 1). The process is detailed below.

![Figure 1: Literature review three steps](image)

**STEP 1:** The research collection starts with a keyword related to the topic Digital twin and Product Design. Digital Twin technology is relatively new therefore papers for this research is not older than 2016. The main source for literature review is Primo, a web-based search tool that provides access to a wide range of scholarly and academic resources, including journals, articles, e-books, databases and more. Primo is commonly used in the academic community and among students. Also, other additional databases such as ABI/INFORM Global, ScienceDirect and Scopus in the research review are used because they relate to Informatics and Computer science. Since the topic is relevant worldwide, all geographic regions are included, with English as the selected language. The selected papers are limited to only review articles, because it is important to be evaluated by experts in the same field before the articles are published. This is a quality
control process that helps to ensure that research holds a high standard (Booth et al., 2016). Literature collection method with the search characteristics is shown in Table 1. Further down, Table 2 shows how many articles are collected within the different databases.

<table>
<thead>
<tr>
<th>Searching Index</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keyword</td>
<td>Digital Twin AND Product design</td>
</tr>
<tr>
<td>Time spa</td>
<td>2016-2023</td>
</tr>
<tr>
<td>Database</td>
<td>Primo, ABI/INFORM, Scopus, ScienceDirect</td>
</tr>
<tr>
<td>Region</td>
<td>Everywhere</td>
</tr>
<tr>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Table 1: Current research regarding Digital Twin and product design from 2016 to 2023.

<table>
<thead>
<tr>
<th></th>
<th>Primo</th>
<th>ABI/INFORM</th>
<th>Scopus</th>
<th>ScienceDirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articles</td>
<td>113</td>
<td>36</td>
<td>11</td>
<td>51</td>
</tr>
</tbody>
</table>

Table 2: Current research regarding digital twin and product design in the selected database. Not all of them are related to digital twin and product design, also many papers are duplicated, so the selection is fewer than the presented.

STEP 2: The screening methods in research include reading the abstract, introduction, and conclusion of all selected papers. If any of these three parts contain digital twin and product design the paper is selected further for review, otherwise deleted. Additionally, a bibliographic trail in the articles is also used for the study. Author points out “by following this bibliographic trail, you can navigate the most difficult research territory, because one source always leads to others, which lead to others, which lead to . . .” (Booth et al., 2016, p. 73). The method helped to find more studies, especially in the topic of user-centered design, some of which were carefully reviewed. To expand the knowledge and learn more about the topic from industry practice, several whitepapers and a report from Ericsson are also selected.

STEP 3: Literature classification is a stage where all the selected articles are intensively analyzed and used further for the study. In total 20 articles were selected for final
review when the keyword Digital Twin AND Product design are used with the defined other search characteristics. Key ideas in the papers and use cases in relation to product design are extracted as well and presented in the Table 3. The literature review helps to understand more on the topic and define different similarities and patterns that were used further in the study.

Research Overview
The first part in literature classification is to make a detailed analysis of the final selection of articles and highlight the different ideas, current usage, challenges and limitations for product design. Overall, the findings are that digital twin technology enables designers to customize, compare and access information through digital twin. Authors argue that digital twins can be strategic for product design development in any organization (Singh et al., 2021, Tao et al., 2019). When digital twin is implemented, it could be used across different stages in product design, from the very first concept to the designing of products and testing. Furthermore, it can improve designers’ understanding of customer requirements through the data and information in digital twins. However, the knowledge about digital twins is still not established in many organizations (Chiabert et al., 2018). Also, the application and usage of digital twin is not yet fully recognized in product design and development and needs further investigation (Lo et al., 2021). In Table 3, below, are described the highlights from the selected articles.

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Article</th>
<th>Database</th>
<th>Key ideas, Use Cases in Product Design. Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barricelli et al., (2019)</td>
<td>A Survey on Digital Twin: Definitions, Characteristics, Applications, and Design Implications</td>
<td>IEEE Xplore</td>
<td>Involvement of workers is needed to collaborate and apply their domain knowledge to improve the twin system. Missing new strategy to support this collaboration between teams. Collaborative design can also help to adapt the software to specific environment and users. A sociotechnical design approach can bridge the gap during collaborative design activities and this approach can be centralized into Human Work Interaction Design known as a part of the Cognitive Work Analysis. The paper also presents the idea of End-User Development (EUD) methods. Different ethical issues, security and privacy, cost of development is highlighted.</td>
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<tr>
<td>Author(s)</td>
<td>Title</td>
<td>Source</td>
<td>Summary</td>
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<tr>
<td>Attaran, &amp; Celik (2020)</td>
<td>Digital Twin: Benefits, use cases, challenges, and opportunities</td>
<td>ScienceDirect</td>
<td>Digital twins use cases and applications across many industries such as construction, manufacturing, aerospace, agriculture, mining, retail, healthcare, military, automotive and public safety sectors. The authors tested different ideas and the collected data can be used to improve product quality and customization.</td>
</tr>
<tr>
<td>Tao et al., (2019)</td>
<td>Digital Twin in Industry: State-of-the-Art</td>
<td>IEEE Xplore</td>
<td>Digital twin applications can be used in design phases such as product planning, conceptual design, and detailed design. Data-driven design framework is presented.</td>
</tr>
<tr>
<td>Singh et al., (2021)</td>
<td>Digital twin: Origin to future.</td>
<td>Primo</td>
<td>“designing/planning, optimization, maintenance, safety, decision making, remote access, and training”. Prototyping and re-designing can be used within the digital twin. Creating opportunities for customization of the product based on user needs and comparison between the actual and predicted product can also be useful. Investigation of different scenarios. Waste reduction and communication improvement. Accessibility of the physical product information regardless of the geographic region. Training is highlighted as a bridge between experienced workers and newcomers. Super realistic models of digital twin can help imitate the physical model.</td>
</tr>
<tr>
<td>Stephanidis, et al., (2020)</td>
<td>Storytelling with Data in the Context of Industry 4.0</td>
<td>Springer</td>
<td>“Visualization and storytelling are powerful ways to take advantage of human visual and cognitive capacities to simplify the business universe.” The paper emphasizes the importance of storytelling in data visualization.</td>
</tr>
<tr>
<td>Tao et al., (2019)</td>
<td>Digital twin-driven product design framework</td>
<td>ABI/INFORM</td>
<td>Digital twins can implement in design for new product in a “more responsive, efficient, and informed manner”. Digital twin applications can be used in design phases such as product planning, conceptual design, and detailed design. Data-driven design framework is presented.</td>
</tr>
<tr>
<td>Lo et al., (2021)</td>
<td>A review of digital twin in product design and development.</td>
<td>ScienceDirect</td>
<td>Digital twin is a possibility for concept generation and provides valuable information for product improvement and redesign. “Digital twin can shorten the development times with virtual prototyping, employing simulation to replace physical testing and supporting design decision making”. The performance and application of digital twin are not fully utilized in DT-assisted product development. Developing product DT in the conceptual design stage can maximize the DT participation in product design and whole product lifecycle”. Concept generation is possible. Communication between stakeholders. Essential is user-oriented involvement.</td>
</tr>
<tr>
<td>Barricelli &amp; Fogli, (2022)</td>
<td>Digital Twins in Human-Computer Interaction: A Systematic Review.</td>
<td>KB+BIBSAM</td>
<td>Human - Digital interaction design is a fundamental aspect for Digital twin’s success. Users are the domain experts. Lack of knowledge and testing with users. Human Work Interaction Design focuses on the how and not on the what of the work activity with the digital twin.</td>
</tr>
<tr>
<td>Zhuang et al., (2017)</td>
<td>Connotation, architecture and trends of product digital twin</td>
<td>ResearchGate</td>
<td>The effective application of the technology of product digital twin can assist and influence the products’ optimization, upgrading, physical control and traceability”.</td>
</tr>
<tr>
<td>Authors</td>
<td>Title</td>
<td>Source</td>
<td>Description</td>
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<tr>
<td>Wagner et al., 2019</td>
<td>Challenges and Potentials of Digital Twins and Industry 4.0 in Product Design and Production for High Performance Products</td>
<td>ScienceDirect</td>
<td>Authors suggest holistic use of digital twins in the full product development process, which requires the involvement of the product designers and production planner concepts. Co-design can be developed with simulation products. Common digital twin interface should be designed for collaboration and for the exchange of information between product developers, planners, and engineers and for mutual understanding.</td>
</tr>
<tr>
<td>Javaid et al., 2023</td>
<td>Digital Twin applications toward Industry 4.0: A Review.</td>
<td>ScienceDirect</td>
<td>Digital twin can provide better knowledge, support development of innovative products and improve product quality. Designers and developers can perform usability of products and develop future product design. It can provide customized products for customers. Digital twin assists virtual prototyping.</td>
</tr>
<tr>
<td>Tao et al., 2018</td>
<td>Digital twin-driven product design, manufacturing and service with big data</td>
<td>Springer</td>
<td>Data-driven product design.</td>
</tr>
<tr>
<td>Dong et al., 2021</td>
<td>Product re-design using functional backtrail with digital twin.</td>
<td>ScienceDirect</td>
<td>Product re-design is broadly used in product development. Redesign process is introduced in digital twin technology to create possibilities for improving on the physical product. The most use cases of product improvement are a redesign process based on existing products.</td>
</tr>
<tr>
<td>Ericsson, 2022</td>
<td>Enhancing innovation via the digital twin.</td>
<td>KB+BBSAM</td>
<td>Service innovation, co-creation and product design. Digital twins enhance service innovation, co-creation and product design. Use case: Inspect with photorealistic environment, that enhances remote site inspection comparable to a physical inspection. Analyzing data and detecting site anomalies. Predict scenarios and design solutions. Collaborate with virtual session and BIM format enables see the information.</td>
</tr>
<tr>
<td>Grieves, 2016</td>
<td>Origins of The Digital Twin Concept.</td>
<td>Scopus</td>
<td>The Digital Twin Prototype describes the prototypical physical artifact. It contains requirements, fully explained 3D model, Bill of Materials (with material specifications), Bill of Processes, Bill of Services, and Bill of Disposal.</td>
</tr>
<tr>
<td>Fukawa &amp; Rindfleisch, 2023</td>
<td>Optimizing Networks with Digital Twins.</td>
<td></td>
<td>The future of digital twins: what will they mean for mobile networks? Digital twins need to be populated with more data: “Training of AI – Most AI algorithms need large amounts of realistic data to be trained”. Future scenarios and deployments will help to upgrade and build network optimally. More detailed analysis requires more detailed data.</td>
</tr>
<tr>
<td>Öhlén et al., 2022</td>
<td>Optimizing Networks with Digital Twins.</td>
<td></td>
<td>Can be used to simulate rollout and design processes. Network performance evaluation. “Further, it enables the early detection of problems that affect product design long before products are deployed, thereby reducing R&amp;D costs.”</td>
</tr>
</tbody>
</table>

Table 3: The final selection of articles related to digital twin and product design.
The last step of the analysis is to organize the findings from the literature review in several categories according to key characteristics. These findings represent the main ideas categorized as potential use cases for product design and development as explained below and summarized in Table 4.

- **Customization**: Several studies point out that digital twins can create opportunities for customization of the product (Singh et al., 2021).

- **Collaboration / Co-creation**: As several studies highlight, digital twin can be successfully used in product design as a common understanding of the requirements and goals between product designers, production designers and production engineers (Javaid, et al., 2023; Wagner et al., 2019). Similarly, co-design can be developed with simulation products and mutual understanding. Authors (Wagner et al. 2019), suggests that the digital twin system must be defined for collaboration and that in that in this way we can bridge the gap among “stakeholders with diverse cultural and professional background” (p. 88). Another aspect is the opportunity to collaborate when the stakeholders are in the different geographical regions. For example, global product development teams can access data in different regions. Collaborative design can also help to adapt the digital twin system to specific environments and users. To enhance the collaboration the paper presents the idea of End-User Development (EUD) methods which consist of methods and tools which support users in extending the system without having specific knowledge of traditional software techniques. (Barricelli et al., 2019, p.167665). Collaboration based on digital twin can be used to support and engage customers by showing them both physical and virtual products (Tao et al., 2019).

- **Concept Design**: As studies point out, digital twin technology can help to conceptualizing the idea of the product (Lo et al., 2021; Singh et al., 2021). Different visualization within digital twin such as 3D models and images can help to better understand the real world and build images that can help further in concept design creation. Authors (Lo et al., 2021; Singh et al., 2021) argue that conceptual design is the first step in the product design process and, to generate a good concept, the designers should consider a large amount of data that can be taken from digital twin. More data can help in improving the communication between the stakeholders and designers.
• Comparison: Grieves (2015) describes that in digital twin we can build a common image and perspective for the physical and virtual product which can give better information about the physical products themselves. The information that digital twin contains about the physical product, such as 3D model and bill of materials, can be used for comparison between different physical products.

• In-depth analysis: Digital twin technology allows us to make more in-depth analyses and increase the reliability of the physical twin. Through the data collection in digital twin on different site solutions we can build a more holistic and detailed understanding of the existing site solutions.

• Re-design: The process of prototyping and re-designing is highlighted in several studies (Tao et al., 2019; Lo et al., 2021; Singh et al., 2021). The authors argue that it is useful in assisting the re-design or product improvement process. The digital twin developed on the existing product can provide valuable information such user behavior and environmental data to enhance the design of next-generation products. Therefore, the study suggests that driven product family design can be further investigated in the future (Lo et al., 2021). Tao (2018) proposed a data-driven design framework where the virtual space will collect, analyze, and accumulate the data from the physical product. The data can be used in design and re-design processes. Another study points out that simulations in virtual objects allow experiments with scenarios, where design and analysis time will be shortened and, in turn, lead to faster prototyping and product re-designing (Tao et al., 2019).

• Virtual testing: Several studies suggest that the simulation of the product can be done with AR/VR technologies and implemented in the digital twin where designers can "see", "touch" and "use" the virtual model especially in the early production design phases. (Lo et al., 2021, p.6). Despite the rapid growth of digital twin, many issues still remain and should be addressed to enhance its viability in practice on focusing of product design can be beneficial for any industry.

<table>
<thead>
<tr>
<th>Literature classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
</tr>
<tr>
<td>Barricelli et al., (2019)</td>
</tr>
</tbody>
</table>

19
Table 4: The characteristic the selection of articles related to digital twin and product design.

A Summary of Previous Research

In recent years, the interest in digital twin from academia and industry has grown. The number of papers related to digital twins and, more specifically, product design opportunities in digital twin is gradually increasing. Within the selected papers, various use cases are highlighted and further categorized based on the key characteristics and common patterns discovered during the classification. Overall, digital twin can be successfully used for product design and development as a tool for collaboration, re-design, concept design and analysis. Also, the digital twin system is an emerging
technology that will enhance transformation in traditional product design and development process. It will play a significant role in the next years to simplify design processes as support testing simulation, prediction scenarios on future product design and virtual testing (Tao et al., 2018; Lo et al., 2021; Singh et al., 2021).

However, twin technology in the product design domain is still in the exploration stage, and more research is needed (Lo et al., 2021). The definition of digital twin is not yet established across companies. Similarly, many of the product design scenarios are still in the area of prediction or implemented in very limited cases. Some of the use cases can be explored easily, such as collaboration and co-creation opportunities among different design teams and stakeholders. However, digital twin technology and its successful usage also depends on the populated data. Training AI algorithms need large amounts of realistic data to be used for detailed analysis. This process can take a long time and a substantial economic investment. Also, building fully expanded 3D libraries will require time and resources. Internal knowledge and awareness for the workers who will use digital twin is also a crucial factor and limited in the moment.
Theoretical framework

For this part of the thesis, there will be a description of the theories which will be used in the study. Going through the principles of each theory and how they will be used in this study.

Human-Computer Interaction and User-Centered Design

Human-Computer Interaction (HCI) is an interdisciplinary field of study concerned with designing, evaluating, and implementing interactive systems for humans. HCI was established as an area of study in the early 1980s (Benyon, 2013, p. xvi). Since then, HCI has evolved into a multidisciplinary field combining knowledge from computer science, design, psychology, sociology, anthropology, and engineering. HCI focuses on the design of computer technology and, in particular, the interaction between users and computers. In the 1990s, actual work was done by the HCI community around the idea of “user-focused software design” (Cooper, 2014, p.104). Today, User-Centered design is a design philosophy that investigates how to design interactive systems that meet people and understand their needs. According to Norman (2013), understanding comes first through observation that people are usually unaware of and examining the difficulties they are sometimes unaware of (ibid, p.9). The desired solution puts human needs first, as a good understanding of technology and psychology. Good design requires good human-machine communication that helps people to understand what “actions are possible, what is happening, and what is about to happen” (ibid, p. 8). In the user-centered design approach, users are at the focus of the design process from the beginning to evaluating the product or system. Also, it refers to how users can influence the design through their involvement in the design process, leading to better acceptance, adoption, and success of the product or system. It is characterized by how designers will understand and see the users use the product, but also to test the validity of their assumptions.

To create a usable application, it is not enough to understand the need of the users but also the user's situation, which includes the context and the environment that influence the user's action toward a task. Many studies argue that this is limited in the user-centered design framework because social, cultural, and historical contexts influence human activity (Kaptelinin, & Nardi, 2018; Kuutti, 1995; Good & Omisade, 2019). One method to emphasize the user context and interaction is with the help of activity theory (Mwanza, 2001)
Activity Theory and HCI

Activity theory as a theoretical framework has been used extensively in human-computer interaction research. According to Clemmensen (2016), the activity theory was first introduced to HCI in the late 1980s. Initially, the theory was used to consider that, in the analysis and design of computing technology, it is essential to know “how people act through technology, rather than interact with it” (Clemmensen, 2016, p. 7). Also, activity theory has been used to understand how people interact with technology in their everyday activities. In human-computer interaction research, activity theory has been used to design and evaluate technology that supports activities in various domains, such as education, healthcare, and work (Bødker, 1989).

The origin of Activity theory is first traced to the classical German philosophy from Kant to Hegel and in the early 1920s, as part of the Soviet Moscow Institute of Psychology with the young researchers Vygotsky, Leontev and Luria (Engeström et al., 1999, p. 19). The mediation model presents the idea that the relationship between the Subject and the Object is not direct and exists through the use of Tools. The researcher Leontev contributed to developing the concept of social and cultural mediation by creating a hierarchical model of human activity. Later, in 1987, the Finnish psychologist and a leading scientist Yrjö Engeström extended Vygotsky's original model and presented an expanded the activity triangle model to conceptualize human activity's collective and collaborative nature shown in Figure 2.
Figure 2: Engeström’s expanded activity theory model.

The activity triangle model presents the Subject, Object, and Community elements:

Tools, Rules, and the Division of Labour.

(Zurita & Nussbaum, 2007, p. 215)

Kuutii (1995) argues that an activity is a systemic whole where elements are related to each other. Tools mediate the relationship between subject and object, rules mediate the relationship between subject and community, and the relationship between object and community is mediated by the division of labor (Kuutii, 1995). The components of the triangle model are explained as follows.

The Subject element of the triangle model refers to the person or group performing the activity that can influence and be influenced by other elements in the model. When subjects pursue the object, their knowledge is transformed by the interaction with the other components of the model. The Objects and the Outcome refer to the goal of the activity. The object is what the subject strives to achieve or produce through the activity. Kuutii (1995) argues that “transforming the object into an outcome motivates the existence of an activity” (p.17). Similarly, this component presents the motivational character of human activity that allows people to control their behavior. Human activity strives to be satisfied with identified objectives. The concept of the object provides
insight into why people perform the actions and are motivated to transform objects into desired results (Kaptelinin & Nardi, 2006). The tools refer to the physical tools or psychological tools to perform the activity. Tools can be physical objects such as computers or applications, or conceptual tools that can influence behavior, such as language practices (Vygotsky, 1978). The tools define the way in which the subject performs the action. The subject can influence the tool to become more effective and this will change the way in which subject uses the tool (Kuutti, 1995, Bannon, 1995). The Community refers to the group with shared interest or culture that interact within the system. This represents the social and cultural context of the environment in which activity takes place. The community includes the norms, values, and practices that shape the activity and influence the interactions between the other elements. The Division of Labour presents the responsibilities and variations in the job roles of the subjects connected to the community. The job roles are based on the experience and skill of the people related to the activity. The Rules represents the norms, regulations, and social conventions that govern the activity. Rules can be formal or informal, explicit or implicit. Individuals, groups, communities, or institutions can create them (Kuutti, 1995).

The author argues that the activities in the triangle model are dynamic, they are changing and developing all the time (Kuutti, 1995). All elements are involved in the development process. New operations are created from the previous action, which is based on participants’ skills increase. At the same time new actions emerge or are being invented, and participants’ motivations can also be undergoing change. Also, external factors influence some elements and that could cause an imbalance between the elements. The author names this event within the activity triangle – contradictions (Kuutti, 1996). Contradictions are defined as problems or breakdowns, and they are seen as an opportunity for development. Related to the triangle model a few key principles are defined as shown in Table 5 below (Kuutti, 1996, p. 13).

<table>
<thead>
<tr>
<th>Key Principles of Activity Theory</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity as the basic unit of analysis</td>
<td>Activity theory suggests including the context of the human action.</td>
</tr>
<tr>
<td>History and development</td>
<td>Activities change over time, and we analyze an activity in order to understand the current situation fully.</td>
</tr>
</tbody>
</table>
Activities are mediated by artifacts and artifacts are created during the development of an activity.

An activity is directed towards an object and the object is what distinguishes one activity from another. The transformation of the object into the outcome motivates the existence of the activity.

Participating in an activity is performing conscious actions that have an immediate, defined goal.

<table>
<thead>
<tr>
<th>Artifacts and mediation</th>
<th>Structure of an activity</th>
<th>Levels of an activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activities are mediated by artifacts and artifacts are created during the development of an activity.</td>
<td>An activity is directed towards an object and the object is what distinguishes one activity from another. The transformation of the object into the outcome motivates the existence of the activity.</td>
<td>Participating in an activity is performing conscious actions that have an immediate, defined goal.</td>
</tr>
</tbody>
</table>

Table 5: Key principles of Activity Theory (Kuutti, 1996).

Several researchers, especially in Scandinavia and the United States, pointed out that by framing human–technology interaction within a larger context of purposeful human activities, the theory makes it possible to reach a deeper understanding of technology and its meaning for people. The researchers Bødker (1989) and Kuutti (1991) argue for adopting activity theory as a theoretical foundation for human–computer interaction and information systems studies. Their works contribute to establishing activity theory as a critical theoretical approach in human–computer interaction and introduce it to other areas of study within the general field of people and technology (Kaptelinin & Nardi, 2012, Nardi, 1996). Involving users in collaborative decision, design, and evaluation is crucial to understanding the complexity of people's needs and how to implement the findings into the design process. Activity theory can help provide a broader analysis and image of a user-centered approach in designing a system and its evaluation. Also, activity theory studies different forms of human practices "with both individual and social levels interlinked at the same time" (Kuutti, 1996, p. 13). Norman (2015) points out that devices work well because they are developed by a deep understanding of the activities they are aimed to perform. He points out that to understand an activity we need to know not only users, but also their activities and tasks related to their work. Designing the activity can help create a more cohesive and better-structured design system. The goal is for the designer to examine and select the proposals for the activity's needs. Uden and Willis (2001), describe several benefits that
activity theory can provide to HCI design. For example, understanding the context in which computer-supported activity takes place during the design process. Also, the approach offers to conceptualize the relationship between the technology, individual and communities (Uden & Willis, 2001, p.4). Usually, it is not specifying which method should be used when using activity theory, but to capture the complexity of an activity model and the subject’s point of view, researchers suggest using qualitative methods (Nardi, 1996.)
Methods.

The activity theory framework refers to a more systematic approach to explore the main research questions of the study. The principles of activity theory and the triangle model will be used to explore the relationship between industrial designers, tools, environment, and the organization. With different qualitative methods, it will involve users in the design process and will try to answer the main research questions related to what insight we can gain with user involvement in the process. The last part of this section is the limitation of the method and research ethics.

Case Company

Ericsson is a worldwide telecommunication company based in Stockholm, Sweden. The company specializes in developing various products and services related to mobile networks, especially in emerging technologies such as 5G. With the increasing traffic growth of 5G technology, new use cases and services have become an opportunity for the company. One of these solutions is a digital twin that "will allow full digitalization of both passive and active site asset management" (Ericsson, 2022, p. 8) Digital twin technology in the telecommunication industry gained popularity in recent years and enabled a variety of innovative use cases (ibid.). The company describes that in the beginning to create site references, they capture rudimentary site assets and configuration knowledge compiled from the logical configuration management data. Typically, there will be access to existing site radio properties, surveys, geo location, equipment placement reporting and incumbent inventory system. From these sources it will correlate in Ericsson’s Site Digital Twin application, using the Ericsson domain knowledge, and also resolve the best-known truth even with inconsistencies to model a very rudimentary site digital twin.

Ericsson Site Digital Twin (ESDT) is Ericsson’s key solution for Asset Digital Life Cycle Management built on open standards, providing an enriched digital twin of the site and network. The solution will allow high levels of automation and advanced insights into network and delivery performance. ESDT interactive portal consists of many tools and provides the capability to get an aggregated and detailed view of the customer's sites. The users can virtually see the site through various views. It also provides a glimpse of the 3D model in the BIM (Building Information Modeling) model. The ESDT portal takes data from multiple sources (lasers, drones, manual, CAD, and
more). It converts the data into a typical, ISO-based digital twin for use cases that address the entire lifecycle of multi-vendor equipment and the network. Different views are represented in the ESDT interface portal as the following.

The Network view consists of the site survey results and gets an aggregated view of all the assets in different map layers. The Spin viewer is the view of the drone survey results in the spin viewer alongside the azimuth angle and drone bearing. Thirdly comes the Point Cloud viewer, where users can see the point cloud pictures in the portal and conduct the needed site measurements. The portal also involves a virtual view representing a virtual site tour. Lastly is the BIM model, a 3D representation of the physical site and a comprehensive component library embedded in the portal (see Figure 3). This library will help add the exact manufactured component parameter and behavior characteristics pre-defined for every component (ibid.). ESDT is in the development stage, and work remains to be done before it’s fully integrated into the industry.

The accelerating 5G rollout with rapid technological development creates opportunities for innovation and new digital solutions for Ericsson. Digital twin technology can support sustainable and digitalized operations, efficiency on network rollout activities, and maintenance of sites (Öhlen et al., 2022). However, digital twin technology is in the exploration space of Ericsson; there is still a lot to be considered. According to report, (Digital twin market, 2022) the interest and implementation of digital twin in telco industry is expected to grow in the next years. One of the main applications where twin
technology will be used across various industries is product design and development (Digital twin market, 2022; Tao et al., 2019; Lo and Zhong, 2021). Authors (Tao et al., 2019) highlight that the digital twin system can enhance transformation in traditional product design and development processes with the user in focus.

User acceptance is essential in emerging technology such as digital twins; therefore, one needs to consider the target group that will use the system (Johnson & Vera, 2019). Writing the thesis work at Ericsson is an opportunity to explore twin technology from a human-centered perspective and a unique opportunity to learn what insights we can gain from a user-centered design approach and what are the limitation when using this approach.

Methodological Approaches: Workshops, Scenarios, Interviews, and User Observations

To gain comprehensive insights and foster user involvement, the study utilized a combination of workshops, scenarios, interviews, and user observations (see Figure 4). These methods allowed the study to delve deep into the experiences, needs, and challenges of industrial designers in the context of digital twin technology.

First, two workshops were conducted to actively engage the participants in the early phases of the design process. During these interactive sessions, the participants created user scenarios that mirror real-world situations and explore potential contributions to the design of digital twins. Detailed information regarding the workshop structure and outcomes will be elaborated upon in the subsequent section.

Second, scenario development methods were employed. This approach involves the creation of detailed user scenarios together with the participants, to depict realistic
situations in which digital twin technology could be applied. These scenarios serve as valuable tools to stimulate discussions, analyze potential challenges, and explore the opportunities and constraints associated with the integration of digital twins.

Third, five in-depth semi-structured interviews were conducted to uncover participants’ previous experiences and knowledge pertaining to digital twin technology. Furthermore, the interviews sought to gain insights into the daily activities of telecom professionals, especially how digital twins might impact their workflow, decision-making processes, and overall work efficiency. The findings from these interviews provide valuable qualitative data that will be discussed extensively in later sections, shedding light on the user perspective and their unique insights into the practical applications of digital twins. Further, interviews with additional stakeholders such as product managers and the design team are conducted to gain more insights into the technology and the business goals of the twin system.

Fourth, to complement the data collected through workshops and interviews, user observations are conducted in real work settings within the telecommunications industry. This method allowed it to gain a holistic understanding of how industrial designers with their work environment, obtain critical information, and confront challenges in their daily routines. By directly observing user behaviors and interactions, the study aimed to identify potential pain points and opportunities for integrating digital twin technology effectively. In the sections that follow, we will delve into the details of each method.

Workshops
Throughout the study, two workshops are conducted, with eight participants in the first session and five participants in the second session.

The workshops take place in Ericsson’s headquarters in Stockholm, in the Design and User Experience Research lab. Naturally, the room has professional recording equipment for user research sessions such as cameras, microphones, as well as ergonomic office furniture, a whiteboard. Also, the room is equipped with a big screen where all participants can see for the first time the twin platform (see Image 1).
During the sessions, we explicitly discussed the workshop's objectives and deliverables with the participants, which, in the context of this thesis study, revolved around the creation of user scenarios from an industrial designer's perspective. All participants are industrial designers, combined junior and senior roles. Iterative workshops allow participants time for reflection and the opportunity to progressively explore usage scenarios and identify limitations. The inherent strength of workshops lies in their capacity to facilitate participant interaction, especially when structured in a positive and conducive environment that fosters trust.

According to Carroll and John (2000) workshops are a qualitative method for collaboration where all participants share a common goal therefore this study follows techniques that refer to “the six P's: purpose, participants, principles, products, place, and process.” These components answer to questions such as why, who, how, what, where and when (Chapter 5, p.2.). The principles are taken and adapted for the study as presented in Table 6.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Participants</th>
<th>Principles</th>
<th>Products</th>
<th>Place</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>What the users can contribute to an early phase of the design process of digital twin?</td>
<td>#1 Workshop 8 Industrial Designers (Senior and junior roles)</td>
<td>Participants agree to recording and filming the workshop</td>
<td>User scenarios for Industrial Designers</td>
<td>Sweden, Stockholm Ericsson, Research Lab</td>
<td>Working as a group Following agenda and questionnaires</td>
</tr>
<tr>
<td></td>
<td>#2 Workshop 5 Industrial Designers (Senior and junior roles)</td>
<td>Participants agree that the collected data be used in the</td>
<td></td>
<td>Tuesday 9:00 – 10:30</td>
<td>Thursday 9:00 – 10:30</td>
</tr>
</tbody>
</table>
In the beginning of each session the aim of the workshop was communicated to all participants. The participants were instructed to give comments about the system they must have the “experience of being in the future use situation, or at least an approximation of it” (Bannon, 1989, p. 9). Therefore, during the sessions, I presented an interactive digital twin platform on-screen, complemented by printed mockup stimuli (see Image 2).

Image 2: Workshop preparation with printed stimuli on the table

Participants will also learn about the twin in the early stage of development and what the possible scenarios and current limitations of the system are. Moreover, the workshops were conducted in accordance with a mutual agreement with the participants, an essential aspect of ethically conducted user-centered research and data policy.

The workshop process stuck to a sequence of pre-decided activities based on an open-ended questions for discussion with the participants, as presented in Table 7. These questions, posed during the workshop, aimed to explore a range of aspects,
including potential scenarios, participants' experiences, their roles, and their knowledge concerning the digital twin.

<table>
<thead>
<tr>
<th>Workshops Questions</th>
<th>Based on the activity theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you have any experience with digital twin technology?</td>
<td>Based on the activity theory</td>
</tr>
<tr>
<td>What are the opportunities for industrial design in digital twin?</td>
<td>History and development</td>
</tr>
<tr>
<td>What problem can (eventually) solve digital twin for product designers?</td>
<td>Community</td>
</tr>
<tr>
<td>What can Digital Twin offer compared to the traditional product development process (without it)?</td>
<td>History and development</td>
</tr>
<tr>
<td>What is the possible use of contexts for industrial designers?</td>
<td>Activity</td>
</tr>
<tr>
<td>What possible limitations you see for industrial designers in digital twin today?</td>
<td>Activity as the basic unit of analysis</td>
</tr>
<tr>
<td>What will be the role of digital twin be for industrial designers?</td>
<td>Rules</td>
</tr>
<tr>
<td>What are the possible scenarios for industrial designers?</td>
<td>Activity</td>
</tr>
</tbody>
</table>

Table 7: Semi-Structured Questions for the workshop

Also, effective facilitation played a crucial role in guiding the group and fostering productive discussions. Throughout these workshops, the participants also had the valuable opportunity to engage in peer learning, accumulate practical experience, and engage in open discussions where they could both agree and respectfully disagree on various aspects.
Scenarios
The scenarios were created in the workshop room and were generated from the participants during the workshops in the form of a common discussion. Everyone in the room actively participated in the discussion and contributed ideas and reflection. The visual support from the shown twin portal and the printed stimuli helped participants to visualize otherwise new and unknown areas. Apart from that some of the participants also used pen and paper to write different ideas for scenarios during the workshop as shown in Image 3.

![Image 3: Scenarios notes](image)

By using user scenarios, the study aims to gain knowledge for the main research questions which refer to insights from the users’ involvement and what knowledge we can obtain when we collaborate with users. On the other hand, industrial designers are familiar with creating user scenarios. This is an established way in software and product development to discover and describe requirements. The scenarios approach was also selected because it focusses on knowing more about the characteristics of the problem and looking at the situation with many different perspectives and interacting with the components of the situations.

This study focuses on the “conceptual scenarios” (Beynon, 2005, p.188). They carry more abstract definitions where some of the details are not highlighted or seen as important. The aim of the conceptual scenarios was to generate design ideas and can bring more high-level definition on the context of use and potential goals or tasks including what industrial designers could do with the digital twin system to improve their product design process. As mentioned, during the workshop scenarios are mostly
generated in the form of discussion from the participants and later organized regarding the ideas in different groups.

Interviews
During the study, one interview session was made with two product managers as main stakeholders of the digital twin technology within Ericsson and one interview was conducted with the design team of the twin portal; also, five interviews was made with the industrial designers.

Firstly, to build more holistic understanding, the sessions with two strategic product managers and the three designers were conducted with semi-structured questions and used most likely to understand how twin technology within network is building, the strategy and current challenges of the twin platform. It was an important part of the study where the goal was to learn more about the broad perspectives where business and organization decisions are involved. The interviews with the managers were in the form of online discussion where they explained different challenges and opportunities of the digital twin. Similarly, the session with the design team was in digital format where we focused on the demo presentation of the twin portal, most specifically on the interface design, current challenges and ongoing research activities.

Thirdly, five industrial designers took part in the semi-structured interviews as target users of the study to investigate their needs and daily working activities, also what the established working practices and requirements are. Authors argue that compared with quantitative data, in qualitative research the number of participants is not that important (Merriam and Tisdell, 2016). Usually, the interview is conducted person-to-person, where the goal of the researcher is to collect special information from the participant. (Merriam & Tisdell, 2016).

The interview sessions with the industrial designers are set in person at the Ericsson main office, where the environment for the participants is known. This creates more intimate settings where the users find it easier to express themselves. Later the answers are summarized with thematical patterns. All the interviews are conducted in a physical setting at the Ericsson office. The conversation was recorded during the session. Also, notes were taken by me with notebook and pen. The study uses an open-ended eight-step model based on components from activity theory (Appendix, Mwanza, 2001). The questions for the interview are based on the model but simplified and adapted to the specific user group and the topic of the study as shown in Table 8.
<table>
<thead>
<tr>
<th>Semi – Structured Questions</th>
<th>UCD and activity theory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Background and intro</strong></td>
<td>History and development</td>
</tr>
<tr>
<td>- Tell me what your role at Ericsson is?</td>
<td>Roles</td>
</tr>
<tr>
<td>- How long have you worked as an industrial designer?</td>
<td></td>
</tr>
<tr>
<td>- How long have you worked as an industrial designer at Ericsson?</td>
<td></td>
</tr>
<tr>
<td><strong>Activity of interest</strong></td>
<td>Activity Community</td>
</tr>
<tr>
<td>- Tell me about the common working tasks in your group?</td>
<td></td>
</tr>
<tr>
<td>- What are the goals in these activities?</td>
<td></td>
</tr>
<tr>
<td><strong>Working tools</strong></td>
<td>Artifacts and Mediation</td>
</tr>
<tr>
<td>- What type of tools are you using in your daily work?</td>
<td>History and development</td>
</tr>
<tr>
<td>- How do these tools help you in your work?</td>
<td>Activity</td>
</tr>
<tr>
<td>- How have these tools developed during the time you have used them?</td>
<td></td>
</tr>
<tr>
<td><strong>Environment (Physical Context)</strong></td>
<td>Physical environment</td>
</tr>
<tr>
<td>- Tell me about your working environment?</td>
<td>Community</td>
</tr>
<tr>
<td>- Do you work remotely?</td>
<td></td>
</tr>
<tr>
<td>- In which settings do you usually perform your work?</td>
<td></td>
</tr>
<tr>
<td>- How would you describe the culture of your environment?</td>
<td></td>
</tr>
<tr>
<td><strong>Organization context</strong></td>
<td>Rules Community Roles</td>
</tr>
<tr>
<td>- What are the roles, etiquette, and guidelines in your team?</td>
<td></td>
</tr>
<tr>
<td><strong>Previous Experience with digital twin</strong></td>
<td>History and development</td>
</tr>
<tr>
<td>- Do you know anything about digital twin?</td>
<td>Artifacts Activity</td>
</tr>
<tr>
<td>- Do you know how to use digital twin in your work?</td>
<td></td>
</tr>
</tbody>
</table>
• Do you have an idea about the functionalities of the digital twin?

Table 8: Semi-structured questions for interviews

After the interview, the summary was sent to the participants, to verify that all information during the interview was understood and is correct. Merriam and Tisdell (p. 246), describe that to verify your data, you can send your summary of the data to the participant. This is called respondent validation. The validation process can be helpful for the researcher to build more trust with the participants. Establishing the trustworthiness and authenticity of the study is important for the respondent to feel safe to know that the data represents them correctly. Also, engagement in the data collection process from the participant helps to come as close as possible to understanding the users. Furthermore, this validation will be important to check if you are biased or misunderstanding what you collect as data.

Observation
The observation process of the users is primarily made in the Ericsson office, more specifically in the Design and User experience studio which is the main working environment of the participants. Also, additional places such as usability and research lab are investigated. The observation of the study began with the listed checklist. When observation is completed, is recorded all information as soon as possible because it can be difficult to later annotate everything that happened during the observation. Also, during the observation process, is used field notes, which usually begin with time, place, and purpose of the observation. Also, during the observation, different activities are created in the form of documents, images, text, and notes. It is important to record as much detail as possible to build holistic image of the participants.

The observations investigated the participants in their working place, daily conversations, meetings, and discussion. Also, looked at more specific details, as the primary aim is to establish an understanding of the social aspect, the rules of the team and community, their tools, and their working activities. The key objective of this observation is to know more about users’ work activities and practices. In that situation,
it is essential for the observer to immerse herself in the user practice and environment (Borgholm & Madsen, 1999).

This can help us to understand better what the future scenarios and context of the use of digital twin applications for industrial designers are and, more specifically, how they will be used in product design. The traditional observation toolbox is helpful; however, as a primary guiding principle for the observation method, this study will focus on the vital component of activity theory described by Kuutti (1996) as shown in Table 9.

Following the principles of the UCD and activity theory, the observation aims to define in-depth the real user activities and needs today, and the historical and social aspects of the activities. The level of confidentiality is important to be promised to the group in order to obtain and record this information.

<table>
<thead>
<tr>
<th>Description</th>
<th>Activity Theory Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the current activities where the digital twin application can eventually support industrial designers, related to the activity object and user motives.</td>
<td>Analysis of the context on the human action and activity</td>
</tr>
<tr>
<td>Activities change and evolve over time. How the activities related to product design are carried out over a time, what changes and how does it change over time. Do they have similar tools related to the digital twin?</td>
<td>History and development</td>
</tr>
<tr>
<td>What are the tools that the users are using towards the goal. Activities are mediated by artifacts and artefacts are generated when an activity changes, and vice versa, the change of the artefact can change the activity.</td>
<td>Artifacts</td>
</tr>
<tr>
<td>What are the rules of the team, the community, and the organization.</td>
<td>Rules</td>
</tr>
</tbody>
</table>
Objects and motives can change during the development of the activity. What are the objects in the different activities for industrial designers?

<table>
<thead>
<tr>
<th>Table 8: Observation guide based on the Five principles of Activity Theory, (Kuutti, 1996)</th>
</tr>
</thead>
<tbody>
<tr>
<td>During the observation, different objects, environments, interactions are considered as seen some of the working places for industrial designers in Image 4.</td>
</tr>
</tbody>
</table>

| Image 4: Observation places |

Data Analysis Method

According to Merriam and Tisdell (2016) every researcher needs to define a system for managing the data early in the qualitative study. The activity triangle model is used as an organizational skim in the analysis part to help organize the data and make sense of it. It is used to explore research questions which investigate what insights we can obtain
with the user-centered design and user involvement and what this approach could mean for the design process of digital twin.

Firstly, different components related to this study are defined in the triangle model as explained below and shown in Figure 5.

The subject refers to industrial designers that are involved in qualitative methods. The tools are qualitative research methods such as user interviews, observation, workshop, and scenarios. The object is the insights obtained with User-Centered Approach, which regarding the design of digital twin represent the valuable findings and understandings gained from the qualitative research activities. The object emphasizes the importance of gaining deep insights into user behaviors, motivations, and pain points to inform the design decisions effectively. Rules are the guidelines in this context which include conducting ethical qualitative research and following the privacy policy of using the data from the application of digital twin. Community consists of the team of industrial designers, the student researcher, and the stakeholders. The community collaborates to plan and execute qualitative research activities and share findings. Division of labor deals with the different roles involved in the project and how they are divided according to knowledge, skills, and interests. Division of labor will be represented by the different roles involved.
roles of the industrial designers, the stakeholders, and the researcher of the study. The motivation is to understand what knowledge we can gain with user-centered design methods in digital twin. The Long-Term Goal in this case is to establish awareness about the user-centered approach in the design of digital twin.

Another research approach used for the data analysis process is coding. It involves systematically categorizing and organizing the data into patterns, themes, or categories to identify insights connected to the aim and research questions of the study. The indication or the coding can be a single word, number, color, or symbol (Merriam and Tisdell, 2016). The coding method is connected to the theoretical framework where different patterns related to the triangle model are investigated. The aim of the analysis is to answer the research questions of the study. According to authors these answers are categories or findings. In the beginning the process starts with defining different categories with the open coding process which means to be open to any possibility at this point. The next step is to walkthrough the notes and group this open coding into analytical coding. This stage is when the researcher starts with the interpretation and the sense of the data beyond the description. Therefore, in analytical coding the goal is to create categories that are abstract description and not the copy of data. The name of the categories can come from the researcher, the participants’ exact words or literature review.

The construction of the categories should be relevant in several bases. Firstly, the categories should be responsive to the research question(s). Secondly, the selected and important data of the study should be fit into categories or subcategories. Thirdly, the categories should be unique and not duplicated data. Fourthly, the categories should be reflected by the sense of the content so the reader can understand exactly what they mean. Fifthly, all categories should have a coherent level of abstraction.

Limitation in Methods
This study explores a digital twin system at telecommunication company Ericsson because it is in the early stage of development and therefore is essential to involve users at the beginning of the process. However, for the qualitative methods, the users' interaction with twin technology is only limited to the current view of the system. Having a complete image of all functionalities of the digital twin could affect how users perceive and interact with the system.
Another limitation of this study is that it explores only the perspective of users from the telcom industry. Also, this study will investigate how we can use digital twin in product design and what insights we can gain with the UCD approach from the perspective of only one group of specialists: the industrial designers. However, the digital twin aims to serve various users and use cases, and taking the perspective of varying target users and be able to compare them might reveal new or different insights. Ideally, a study with all target user groups would be beneficial for a more comprehensive view and broader image of user needs. Nevertheless, this study is connected to one user group and one industry because of the time-limited format.

Lastly, for most of the period the thesis was conducted, the access to the digital system was not accessible due to the development process. Therefore, exploring the digital twin system in an iterative way with users is limited due to the timely delivery of the thesis.

Research Ethics
Research ethics are essential for every study, so researchers must follow official routines regarding participants and their safety and well-being. Ethical rules ensure the researcher is guided throughout the research process (Byrne, 2016). Usually, when conducting interviews, observations, and workshops, there is a mutual agreement between the participants and the researcher. Byrne (2016) describes four basic principles of research ethics that every researcher should follow. Firstly, protecting the participant’s interests means you are not exposing the participant to a harmful situation. Secondly, one must inform the participants about the purpose of the research and guarantee that they are participating of their own will. Thirdly, the researcher answers honestly if the participant asks a question. The last principle is that the researcher follows the national law. The four-research principle is the baseline and must be followed by any researcher; only with permission can the research be published. Following the principles, this research informs the participant about the purpose of the research before the interview is conducted. Communication is the key to the following information transparently. The materials are not shared for any other research or study, and the names of the participants are not revealed to anyone. In any research project it is crucial to ensure that the answers collected in the interviews is used only for the purpose of the research you are conducting. Therefore, a mutual agreement between parties can guarantee that participants’ identities are kept safe, and the answers are
correctly used. Each interview is transcribed and discussed with the participants if they want to comment or add anything new. The transcription is shared only with the participants (Byrne, 2016). During the qualitative methods, it is essential to listen to users and give them the freedom to express their thoughts and insights without feeling pressured. Another fundamental principle is to ensure equality and inclusivity by working with a diverse range of participants. Ethical research also requires transparency and honesty in how insights are gathered, analyzed, and presented in the findings section.

Doing research in the domain of digital twins raises other questions relevant to research ethics. Data-related issues are one of the main challenges when it comes to product design development and more specifically the concerns related to confidentiality, ownership, and regulation of the data. Digital twin requires the collection of huge amounts of data, that often can include personal or sensitive information. By ensuring the privacy of the data and the security we can protect society from unauthorized access and usage. Data protection should follow privacy regulation and always accurate maintenance. Different regions and countries can limit access to the data, and that adds limitation for the digital twin beyond the complexity of the technology. External parties such as customers and governments may not agree to use their private information in product design. However, the problem can be solved with agreements and clear regulations from the parties involved (Lo et al., 2021, p. 11, Singh et al., 2021, p.14). The research strictly follows the code of conduct of data privacy from the digital twin user policy during the testing. Respecting the user's autonomy and privacy is a key factor for user-centered design research. Handling and proper storing obtained data are important factors for building trust and covering ethical standards.

Also, from the perspective of societal sustainability digital twins can have significant energy consummation, infrastructure requirements and waste electronic waste. It is crucial to design and implement digital twins with sustainability in mind, considering different impacts on the environmental footprint and lifestyle changes.
Empirical Findings and Analysis

Here, the empirical data and artifact analysis will be presented. The analysis process will follow the triangle model of the activity theory and will present the findings and analysis as first refers to findings in qualitative methods with the included workshop activities, scenario activities, and interview responses and observation. After that will be presented the findings from the interaction with the different stakeholders of digital twin system, and rules and guidelines of the usage. In the end the summary of findings and analysis will be presented.

Findings from Workshops and Scenario Development

In the beginning, two workshops are conducted with industrial designers where they created different use scenarios related to their working needs and imagined how they can apply digital twin technology in their working tasks. The goal was to understand and learn what we can gain with the user-centric approach and how the collaboration with industrial designers can be used in the design process of the digital twin.

The industrial designers generated many different scenarios during the workshops. Most of the scenarios involved conceptualization, focusing more on the “why” industrial designers want to use digital twin, which was mainly based on their current challenges or needs and “how” that could be achieved in a digital twin portal. During the workshop sessions they could imagine and describe different scenarios based chiefly on their working practice, current working limitation, and experience. It is noticed that when user attend for a second time a workshop the designer can generate more scenarios are more specific than in the first attend of the workshop. However, the early development and limited functionality of the digital twin makes it more difficult for them to see all possible scenarios in the glance. After coding analysis, the user scenarios were described and organized regarding patterns into different categories, as explained in Table 9 below.
| Holistic site understanding | The participants argued that the interaction with digital twin can help them in a more holistic understanding of site. Usually, they are working on a single product design but cannot always “see” how the designed product relates to other components on site. Different visuals and views in digital twin would help them to capture the more complete image with the equipment included on site and their different variations across the globe. Having the image of different site types as a reference in the development process would make it more transparent for all what they aim for and what impact different solutions or choices bring. |
| Extract statistics and data | Twin technology would increase awareness of site deployment alternatives and interdependencies. The participants could extract statistics from the available data and generate type sites in various ways. It could be per region, per operator, or through other site context aspects like “rural tower” or “big city rooftop” deployments, and more. By utilizing photometric scanning technology, both handheld and drone mounted, one designer could capture a full site and use the material, combined with the BIM model library, for many engineering and planning tasks in very short time, with very high accuracy for various of steps in the design process. |
| Close to stakeholders and customers | Access to different site solutions would bring awareness of the development process, spread the knowledge of the real-world sites, and break the “one box in a silo tendency” that occurs too easily. The materials could be used further in the discussion of concepts and solutions with customers as a reference based on their specific site solutions. |
| Onboarding and Learning | The participants highlighted that digital twin could be used as a learning tool for onboarding of new employees. “Traveling” to various of site solution in different regions would be easy and more sustainable with digital twin. New employees would learn faster about the specific equipment and grasp the knowledge from a real-world solution. |
| Understand the installers challenges | By accessing various packets of data from different site locations, industrial designers can imagine and understand better the possible challenges for installers, related to products, deployment, and the surrounding environment. This is an opportunity to predict and create more empathy about what installers face in their everyday working environment. |
| Virtual usability | The participants see the possibility to practice usability testing in the virtual space of digital twin. They could test different “what if” scenarios related to physical products. |
| Yearly meteorological analysis (ESDT portal new function) | The participants highlighted that meteorological conditions are important to understand the overall landscape around the site solution. Adding meteorological analysis in digital twin would help better understand how weather can affect product design decision towards more sustainable solutions. As an example, they point out that in different regions a lot of snow and ice can be expected to come. Often questions are related to weather conditions and how we will affect the products on site. Therefore, seasonal, and yearly time information can be valuable information. A possible idea could be information on historical meteorological conditions of the site and planning site solution based on the results. |
| Thumbnails section (ESDT portal new function) | Digital twin consists of many different visualization and data related to a single site. Similarly, a large amount of data is involved in different projects and quick visual summary would make it easier to review the information related to site. Industrial designers propose a section with short visual representations like a thumbnail of a project. |
| Last updated information (ESDT portal new function) | Industrial designers point out that site solution equipment can be modernized over time with newer products. It is important these changes be documented and highlighted in the project. They proposed the idea of a ‘last updated information’ section. This would help to know when the last changes were made on site and which products were affected, which would help make more informed fact-based decisions. |
Searching for key words could make the process of finding specific information on products faster and easier. This function in the interface can help to easily navigate the range of products existing in the different site solution.

<table>
<thead>
<tr>
<th>Key word filtering (ESDT portal new function)</th>
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<tbody>
<tr>
<td>Searching for key words could make the process of finding specific information on products faster and easier. This function in the interface can help to easily navigate the range of products existing in the different site solution.</td>
</tr>
</tbody>
</table>

Table 9: Scenarios generated from industrial designers.

Findings from Interviews

As another qualitative approach, few interviews were conducted with the industrial designers that participated in the study and two interview with stakeholders such as product managers and design team. The purpose was to learn about the industrial designers’ previous experience with the digital twin technology and the current the challenges at work. The interviews with stakeholders and design team focus mostly to understand the business perspective of the organization and to learn about the digital twin technology and the current development plan of the twin portal.

During the interviews with the industrial designers, one of the topics we discussed was about working tools and practices. When we talked about product design processes, one of the users stated, "I've been on site once. We need all the facts on the table" (Personal communication, 2023-04-13). The user explains the importance of examining products in real-world situations and environments. Stories about network deployment where global or local issues in installation process and products are discussed. The members share various stories based on their experiences, between each other. The experience of working in the field is very prominent, and often used as a reference in a variety of topics. Also, different rules, limitations and regulations related to the product design are discussed. They emphasized the importance of interacting with users of the products and having their feedback.

Much of the discussion focused on challenges that industrial designers face today. For example, a user highlighted they "need more information and data to understand the big picture. Need to bounce the idea with reality" (Personal communication, 2023-04-13). The participants discussed the need to understand the holistic picture and the actual context to be able to compare. When talking about working tools, a participant pointed out the complexity of producing a new product and the different design stages to realization. The users mentioned that they use paper and pen as a starting point for
many of the processes and, later in the process, move to the digital environment and the 3D prototyping and modeling. According to one user, something that is missing is the more "physical hands-on work" (Personal communication, 2023-04-13). On the opposite side, controversially, another user believed we needed to involve more AI in our working process. This shows that different users in the same group can have completely opposite views and visions of the work. Another interesting conversation was related to the significant difference in network deployment in different regions globally. One of the industrial designers explained that the difference in working conditions (during the deployment process and ways of working) in different regions globally are essential information. They emphasized that it is important to have more global and local knowledge about different processes and even cultures. Different markets require different solutions. Industrial designers show high interest in learning about differences in installation practices and challenges for humans. One of the highlights was that in usability labs they cannot see the real-life situation, and the environmental effects of the process. For example, when someone working long hours outside is exposed to various weather conditions and the performance of the product installation is not the same as if it were taken in a usability lab. In many of the stories, industrial designers highlight new technology as an important driver for product development. However, building trust with people and knowing their behavior takes time and effort and usually happens in the real-world interaction with physical world. They highly believe in user-centered philosophy, but due to many external factors and challenges it can be beneficial to adopt digital twins in the process.

Industrial designers have established working practices and routines. Digitalization and highly automated processes they see as an opportunity for their work, but also as a threat that will take them away from the hands-on way of creating product design and meeting people in real life. Implementing new technology is also directly connected with the motivation of the users. Offering new “tools” also requires knowledge and time to imagine and test what can be done with this tool. Still, digital twin is not seen as a bigger influence or game changer for industrial designers and changing the working practice can take time and effort. More generally, the observation process, which nevertheless requires effort and time, can give a more interesting perspective, and can allow to get close to the users in their daily working life. The concern is that if there is too much attention to current activities and needs, one could miss the opportunity for totally new innovative solutions outside of the common challenges. They
are familiar with their way of doing and often accept the limitations in their work environment as a part of a higher-level decision that is difficult to influence directly.

Findings in Interaction with Stakeholders
In the beginning, the study initiated a meeting with the first group of stakeholders. The purpose was to understand and learn about the current development of the digital twin at Ericsson. The discussion focused on the current stage of the system and different roles and areas of responsibility. During the conversation, a few interesting points were mentioned, for example about the different end use case within digital twin. One of the stakeholders highlighted that twin portal is used as an enabler for end use cases and depending on the end use case you want to fulfill, and depending on the level of efficiency or accuracy you want to fulfill you have different usage of digital twin. In that way, we might need a different level of a digital twin, which means a different level of purpose or efficiency (personal communication, 23-02-08). This is interesting statement because it enhances the question of what the purpose of digital twin for industrial designers is and what the level of efficiency for their use case is. Also, it highlights how the process of defining different users can influence the digital twin strategy and development. Different types of digital twin mean different things to different users and defining who the end users are could help to focus on understanding the different contexts of use too. During the demo session with other stakeholders the prototype and different components of the system were shown. We also walked through different parts related to the interface design. Some of the early discussions with stakeholders showed that twin terminology must be defined so that everyone uses it in the same way. An example is the “Site types” and “Type sites” that was applied differently in some of the communication (Personal communication, 2023-03-17). The process of alignment of different internal terminology can also be beneficial especially when it comes to developing new technology and discovering new territories.

The stakeholders pointed out that industrial designers are not seen as a “target user” of the digital twin but the users’ input related to physical products and 3D views can be beneficial for the digital twin (Personal communication, 2023-04-13). Industrial designers have domain knowledge that might be valuable to bring in the design of digital twin. Furthermore, stakeholders can influence important decisions such as including or excluding different target users based on goals or other corporate motives. None of industrial designers used or worked with digital twin before, and the group
knowledge about the twin technology is very limited. Varying years of experience and knowledge can influence the interest in the digital twin differently and their motivation.

Industrial designers pointed out that access to all data can be an issue because different regulations in different counties can limit the access to data in the digital twin. Different concerns that are raised from the users refer to confidentiality, data ownership, and regulation of the data. For example, guidelines on how to use the data and who can access this data are a crucial aspect for industrial designers’ activities. Also, different regions and countries can limit the access to specific data and that adds limitations for the digital twin beyond the complexity of the technology. The external parties may not be allowed to use their corporate information for product design purposes. Data silos can be a limitation for the future adoption of the digital twin. Therefore, it is essential for the users to know the data guidelines and usage in the digital twin.
Discussion and Conclusion

*In the final part of the study, we will go through the reflection and evaluation of this thesis. We will go through the RQ's and examine if they were answered. Lastly, we will discuss what could be suggested for future studies.*

RQ1: What insights could be obtained with user-centered design and user involvement for the design of digital twin within the telecommunication industry?

As mentioned in the Introduction, the digital twin is an emerging technology gaining popularity across industry and academia. Most end users of the digital twin are experts in the specific domain in their industry (Barricelli & Fogli, 2022). Bannon (1989) argues that people are not naïve when it comes to their work and can contribute with their knowledge if the design team collaborates with them. However, today there is a missing adoption of a user-centered design approach and user involvement that might be helpful in the design process of digital twins (Barricelli & Fogli, 2022). According to one of the study's stakeholders, a digital twin is an enabler for end-use cases. Depending on the use case, a digital twin is used differently from various of users (personal communication, 23-02-08). At the same time, discovering all possibilities for various end-use cases might be challenging for designers because digital twins can be used differently for different purposes (Javaid et al., 2023). Therefore, applying the fundamental principles of usability and user-centered design, which is to know and involve the users in the process, can help designers better understand what is essential for various users and how to achieve it in the design of the twin system. Workshops and scenarios are used in the study to help users reflect on the possible usage of the system from their perspective. The results show that the users "materialized" otherwise new and abstract fields of digital twin and started reflecting on more concrete solutions related to their work. Involving users can be beneficial, especially in new technology, because workers know the specification and the gaps in their work and can directly be connected to that in discussions with the designers. During the workshop, the participants often expressed examples of their daily challenges, tasks, or limitations. Reflecting together with industrial designers on specific scenarios also helped understand user motivation and the context of use for them in the digital twin. This approach shows the practical-oriented design side of their expertise because they can develop concrete solutions and identify problem areas in their working activities. During
the study, industrial designers started getting to know the twin system and what could be possible for them and to have the opportunity to articulate and share their ideas. Furthermore, the conducted interviews and observation added an extra layer of knowledge about the users because these methods broaden the understanding of the industrial designers. For example, what are their challenges today to perform their work, their cultural norms, ways of working, and even historical knowledge on a variety of tools they are using and what is new in their toolbox. During one of the interviews, one of the industrial designers commented that "everything is in the details" and "I need all facts on the table" (personal communication, 23-04-13). Knowing details and broad aspects of facts can be a powerful tool for them when exploring new product design ideas. For example, different extra details in digital twins as a layer of information and opportunity to extract data can help them define and refine their design solutions with a more data-driven approach.

One of the findings from the study is that, when involving users in the process, curiosity might increase regarding additional and different areas related to guidelines and rules, such as what the data guidelines and regulations to access information are on different site solutions and to use the data for the purpose of product design. The collaboration between users, designers, and stakeholders can be a valuable tool for transparency, to gain knowledge about the digital twin goals, and to get mutual perspectives. During the research methods and analysis, the results showed that different components in the triangle model are interlinked and interdependent, and the decisions and preferences of the users are affected by different components. For example, the level of interest and predominance of ideas can be related to different roles, and the community can influence user engagement. Different user-centered methods can help gain an understanding of users differently. Gould and Lewis (1983) argue that users and their tasks should be in focus; also, they should test the product or the system, and the testing process needs to be iterative. The first step for every designer is to know who the users of the product or the system are. The users of digital twins can come from a variety of different domains. This study focuses on industrial designers as potential digital twin users, even though some stakeholders needed to see them as target users. Understanding industrial designers' characteristics helps to know what their work specifications are better and what they can accomplish in digital twins. The insight that user-centered design can bring is the specific knowledge in their domain that the users can pass on to the design of the digital twin. Also, will be valuable for comparison with other users of the digital twin system. For example, during the
workshops, the industrial designers created scenarios related to their work challenges and specific needs. The scenarios can build a richer image of the potential users' needs in the system and what functionality they seek to improve their work. One of the users attended the two workshops, and one observation is that the participant provided more new ideas during the second workshop. The impression is that the industrial designer reflected and processed the new information from the first workshop and came more confident and knowledgeable to the next workshop. Iteration design can allow the user to exercise the information, learn better, and generate more ideas in the second round. The generated ideas from a diverse range of users can be assessed and ranked based on the varying importance to individual users, allowing for the prioritization of different needs.

RQ2: What limitations could user-centered design and user involvement incorporate in the design process of digital twins?

Norman (2005) argues that if we are designing tools and products for today's users, the design solutions might not be suitable for tomorrow. He says that when the individuals learn about the system, they are no longer beginners after some period. Also, he argues that the "individual is a moving target" and we need to consider that users gain proficiency in usage, and needs can change over time (Norman, 2015, p. 16). One possible challenge of user-centered design could be if we focus only on the findings from today and accept them as a constant measurement and guidance for design decisions. The user knowledge and preferences could change over time, which needs to be considered when designing digital twins. The user-centered design might be limited to give the designers insights only on the current status; however, the requirements change, the users' preferences can evolve, and the users can discover new needs to perform their tasks. On the other hand, as digital twins evolve and new functionalities and applications develop, it can be challenging to know how users perceive and evaluate information based solely on measurements that are gained before the new design is implemented. Naturally, a user-centered approach should be integrated into every stage of development, with ongoing measurement and evaluation of the product or system.

According to this study another limitation could be that this study is taken from the perspective of only one group of users; however, the digital twin has different types of users, and all of them can bring many perspectives or needs that could be difficult to
apply in the twin system. Designers and stakeholders need to balance various user needs and ensure feasibility within the technical frame, timeline, or other limitations. User-centered design should be applicable as a broad approach within the various user groups that will help designers compare and map various insights. However, taking into account only one group can decrease the chance of making a system suitable for various users.

Another common challenge during the study is the time-consuming process of collecting all the qualitative data. User-centered design methods take time and resources, especially for iterative sessions. In rapidly growing digitalization, economical turbulences, and the high speed of product development, there is concern about how user-centered processes can be used and implemented as a mindset if costly and time-consuming. Also, user feedback can involve multiple cycles of discussion, prototyping, and testing that could be difficult to follow up on due to time issues. During the scenario's methods, one of the challenges was that the users generated many scenarios. However, when sorting the scenarios, many seemed challenging to realize or very specific for the product design. To design for all users, it is essential to know all the included target users' perspectives and needs. Another challenge is that users can be stuck in their established way of doing things. Exploring new technology takes time and not always, if we only ask users, it is possible for them to immediately "get out" from their old way of doing. By combining the user-centered approach with other frameworks, we could expand the knowledge with more diverse perspectives on stakeholders, rules, and roles, which ensures a more holistic and effective design process. However, using only user-centered design can be limited to the perspectives of users and their needs, and we might miss the chance to look at the bigger picture.

By using the activity triangle model, the study aims to build more holistic knowledge about the users and their environment and investigates different relationships and interaction between all components of the activity model. The key findings are organized into different patterns and summarized as shown in Figure 6.
In Figure 6 is presented a summary from qualitative approaches, user activities, and insights derived from rules, community dynamics, and division of labor. These categories serve as the primary wellspring of insights in the study. The green and red colors indicate the positive insights and limitation defined from user-centered approach. As the findings reveal, some insights are recurring themes shared across different qualitative approaches, like the time-consuming process and the users “materialized” the subject during the workshops and scenarios. Conversely, some insights remain category specific.

Concluding Words
This study follows how industrial designers use different qualitative methods such as workshop and interviews as instruments and based on the different findings we explored what these methods bring as insights and limitations. During the workshops the industrial designers generated many scenarios that are focused mostly on their current working challenges. One of the issues is related to missing the full package of facts, where they see that digital twin eventually can fill this gap. Furthermore, with the qualitative methods, such as interview and observation, the study built more solid images of the industrial designers as a group, their interests, ways of working and
issues. Using different tools, we explored the working practices of the industrial designers, and this helped us better understand their current challenges in the work related to tools and processes. In the findings part we also better understood the relationship and interdependencies between different components in the triangle model and what insights we can obtain from user-centered methods. For example, industrial designers are aware that the process of accessing data in digital twin depends on companies' agreements and local regulations. The level of communication between the organization and the user can affect their understanding and motivation towards the digital twin. Another finding shows that users are experts in their work and practice their work in familiar ways. A new system means new knowledge, which requires time and effort to understand. The process of knowing digital twin system strategy and the collaboration between different stakeholders is essential to build a more complete image. Knowing users also means that we understand the difference between their roles and needs and that can help make a more accurate analysis.

The results showed that user-centered design could be valuable at various levels. Firstly, the user-centric approach can help the designers use the users' domain knowledge and design a more accurate and usable digital twin system that can be applicable and improve their working tasks and practices. Secondly, the approach can identify specific user challenges that can be considered in the design stage of the digital twin. Thirdly, the insights showed that collaboration between designers, users, and stakeholders led to a better understanding of the perspective of every group.

Looking at the perspective of future technology and how people will adapt to it, the complexity increases and requires various tools and methods to tackle the problems. Knowing where user input is crucial in the design process, and when and how often we need to conduct user research is also essential. User-centered design helps users to prepare for their future as they learn about new systems. However, building new technology is a complex process that needs careful understanding when it is essential to bring user insights as a part of the whole puzzle. People are at the heart of every technology, and knowing and collaborating with the users increases the chance of designing adaptable and friendly digital twin systems that will bring valuable contributions to the future.

Future Research
New technology as a digital twin emerges in our working environment, and by
continuing this path of study, we can further investigate how this technology will affect people and how they will interact with this new technology. The domain users are the end users in the digital twin who carry in-depth knowledge and expertise in a specific industry area. People are sources of knowledge and inspiration and can give various perspectives that help build more usable and friendly technologies. Therefore, it is essential to consider all end users of the digital twin when building the system. Future studies can explore more users group and compare different results. When involving them, we can ensure that the design of the digital twin system reflects their needs to perform their work in the best possible way.

Furthermore, this study uses activity theory to create a more holistic image for users, stakeholders, and the environment, including rules and roles. It would be interesting to explore and compare other cognitive approaches and see what the results could be. Also, it would be interesting to investigate what insights could be obtained for the research field with a more systematic measurement over time and track how the users’ insights change after growing more familiar with the digital platform.

Lastly, another possible research path will be to explore where in the design process of the digital twin will be most valuable to bring user-centered design and how this method will be combined with other approaches as a potential systematic research framework.
Sources

https://doi.org/10.1016/j.dajour.2023.100165

https://doi.org/10.7146/dpb.v18i290.6668


https://doi.org/10.1016/j.aei.2021.101297

https://doi.org/10.1016/j.procir.2019.04.330

https://doi.org/10.1007/978-3-030-23541-3_1


Cambridge, MA: MIT Press.


Personal Communication (interviews)
The interviews were recorded and transcribed

Personal communication 1: Digital Twin, Stakeholder #1 (Ericsson) (2023-02-08)
Personal communication 2: Stakeholder #2, general discussion (2023-03-07)
Personal communication 3: Stakeholder #3, Digital Twin demo session (2023-03-20)
Personal communication 4: Stakeholder #4 (2023-04-12)
Personal communication 4: email communication #1 (2023-03-17)
Personal communication 5: Interview #1 with Industrial designer (2023-04-13)
Personal communication 6: Interview #2 with Industrial designer (2023-04-13)
Personal communication 7: Interview #3 with Industrial designer (2023-04-13)
Personal communication 8: Workshop N1 (2023-04-18)
Personal communication 9: Workshop N2 (2023-04-20)
NOTES

1. “The Russian language has two words, objekt and predmet, both of which are typically translated to English as “object.” Leontiev (1959/1981, 1975/1978) used predmet, to denote “the object of activity.” In Russian objekt and predmet have very similar meanings, and in many contexts are fully interchangeable. However, there are some subtle differences, which are difficult to grasp even for many native Russian speakers. Although objekt deals mostly with material things existing independently of the mind, predmet often means the target or content of a thought or an action (Kaptelinin, 2005, p.6).”
Appendix


"Activity of interest
What sort of activity am I interested in?
Object or Objective of activity
Why is this activity taking place?
Subjects in this activity
Who is involved in carrying out this activity?
Tools mediating the activity
By what means are the subjects carrying out this activity?
Rules and regulations mediating the activity
Are there any cultural norms, rules or regulations governing the performance of this activity?
Division of labour mediating the activity
- Who is responsible for what, when carrying out this activity and how are the roles organised?
Community in which activity is conducted
What is the environment in which this activity is carried out?
What is the desired Outcome from carrying out this activity?"