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# User Experience of PLM-Systems Analysis of the Current State of Research

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**Abstract.** This paper sets out to analyse the current state regarding the user experience (UX) provided by PLM environments. Our literature review sets focus on commonly used methods in UX research, and the identification of research gaps regarding UX in the field of PLM. The resulting list of research methods and gaps was allocated to previously defined research questions. This leads to an extensive list for further research, highlighting the gaps, describing the questions, and proposing methods on how to bridge these gaps.

**Keywords:** User Experience, UX, Human Computer Interaction, Human PLM Interaction, Human Centricity

## 1 Introduction

What does it take make employees love their PLM systems? This initial question raised from an interesting observation in industry. While most software engineers love their code repositories and DevOps tools almost in an emotional way, mechanical engineers and other PLM users often do not feel very comfortable with their data management solutions. So, what is going wrong in PLM? To answer this question, we first need to understand what defines the user experience in PLM.

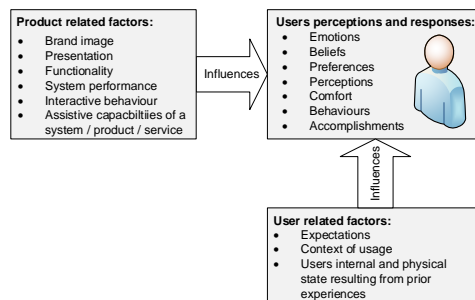
UX is a widely researched topic. The insights of this field have changed the way we interact with products and especially with computers. For several reasons we believe that further research is needed to enhance the UX provided by ICT tools in the field of PLM. First, initial studies have shown that the overall user is not very happy with his tools [1]. Second, the implementation of PLM environments has originally been driven by the complexity of data and processes. This led to tools that excel in the backend aspects but have not been developed with a clear user focus. Third, the acceptance for low levels of usability and a poor overall UX is dwindling. The high levels of usability provided by consumer software leads to higher expectations in the work environment. [2] The fourth and last point, is that PLM environments often consist of a unique mix of different tools. Which creates an additional challenge for the user. An engineer may need to use multiple tools to complete a given process step. Even if all these tools by themselves offered a high level of usability, the sum of the tools and their (possibly) different usability-philosophies may lead to a very poor over all UX. This is a point

which is hard to overcome for a single tool provider. It requires the development of standards and general approaches for PLM environments.

## 2 Current State of Research

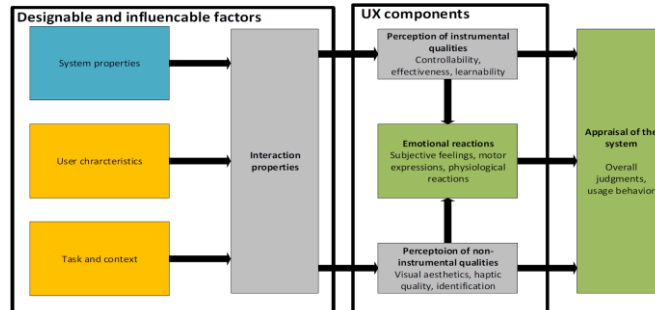
### 2.1 Components of UX

The term UX is used in various contexts and is ambiguous [3]. Law et. al conducted a survey among 275 researchers and practitioners. The goal of this survey was to evaluate the usage of certain definitions of UX. The most picked definition is in line with the one made by the ISO [4]. Therefore, the definition of the ISO can be considered suitable to clearly define UX and its scope. UX is described as "A person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service". The standard describes several factors influencing the resulting responses. Hereby two main categories of influential factors are used. These are the product-related factors and the user-related factors. An overview of the categories is shown in the figure below. [5]



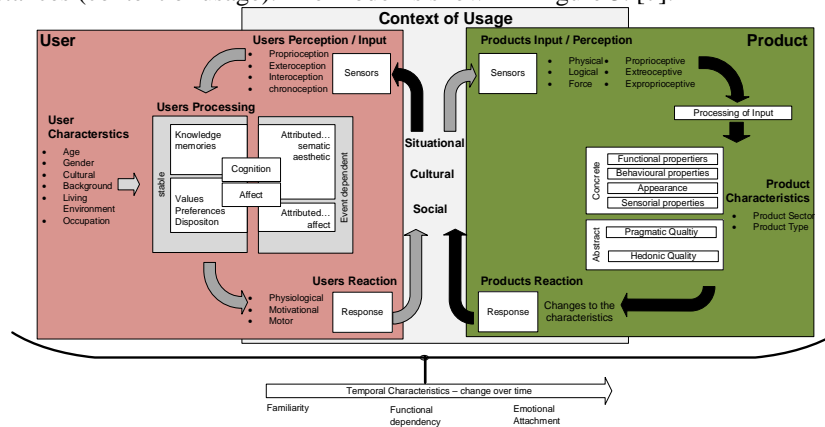
**Fig. 1.** ISO 9241-11 definition of UX

Factors making up the UX have been subject to research. Various models have been developed to describe the interaction of these factors and their relevance to certain aspects of the UX. Thüring and Mahlke propose a model that includes factors such as aesthetic qualities, emotional experience as well as instrumental aspects (usefulness and usability). The model is based on three experiments highlighting the importance of non-instrumental qualities in UX research. An overview of the model is given in **Fig. 2** [6]



**Fig. 2.** Component of User Experience Model

A different model has been developed by Bongard-Blanchy and Bourcard. This model is based on findings from the field of neuroscience. The model aims to help designers and product developers to gain a more holistic view of UX. It describes the UX as an ongoing direct interaction between a system and a user. Hereby both, the system and the user, try to interpret the signal given by the counterpart. After the processing of the input they react as adequately as possible under the given circumstances (context of usage). The model is shown in Figure 3. [7].



**Fig. 3.** Components of UX

The model of Bongard-Blanchy and Bourcard and the model of Thüring and Mahlke can both be abstracted to the same three main areas. These areas can also be found within the definition made by the ISO. This leads to the conclusion that UX has the following main components:

1. The Users Characteristics
2. The Context of Usage
3. The Products Characteristics

Kujala et al. argued, that the experience of a user changes over time. According to their analysis, UX often consists of hundreds of interactions between the user and the product. Thus, they conclude, that UX is influenced through current but also by

past experiences. This means that the components of UX dependent on the user's history. Thus, time may change the UX provided by a product drastically [8].

## 2.2 Evaluation of UX for Software Products

After establishing a clear-cut definition of UX and its components the question arises. How can the overall UX and its components be evaluated? Several different approaches have been proposed. Rivero and Conte performed a systematic mapping study, aiming to categorize the available methods for UX evaluation. In total they identified 227 evaluation technologies. The attributes of Table 1 were used to categorize the technologies. [9]

**Table 1.** Categorization of UX evaluation Methods

<b>Type of Technology</b> <ul style="list-style-type: none"> <li>• Written Reporting</li> <li>• Oral Reporting</li> <li>• Observation / Monitoring</li> </ul>	<b>Assesed Period of Experience</b> <ul style="list-style-type: none"> <li>• Before Usage</li> <li>• During Usage – Single Episode</li> <li>• During Usage – Long Term</li> <li>• After Usage</li> </ul>
<b>Information Source</b> <ul style="list-style-type: none"> <li>• Users</li> <li>• Development Team</li> <li>• UX Experts</li> </ul>	<b>Collected Data</b> <ul style="list-style-type: none"> <li>• Qualitative</li> <li>• Quantitative</li> <li>• Both</li> </ul>
<b>Location</b> <ul style="list-style-type: none"> <li>• Controlled Environment</li> <li>• Field</li> </ul>	<b>Supports Correction of identified Problems:</b> <ul style="list-style-type: none"> <li>• Yes</li> <li>• No</li> </ul>
<b>Type of Assessed Application</b> <ul style="list-style-type: none"> <li>• Generic</li> <li>• Web Application</li> <li>• Mobile Application</li> <li>• Other</li> </ul>	<b>Availability</b> <ul style="list-style-type: none"> <li>• Available for Free</li> <li>• Available under a license</li> <li>• Not publicly available</li> </ul>

The work of Rivero and Conte is based on the analysis of Vermeeren et al. published in 2010. Vermeeren et al. analyzed and categorized a total of 96 methods. They concluded that there is a need for additional methods. These methods should focus on the early phases of product development. Additionally, they empathized the importance of the practicability of the methods. Another point raised is the need for multi-method approaches. Vermeeren et al. argued that several methods focused on certain aspect of UX. The combination of methods may lead to more holistic analysis. [10] In their update of the first analysis by Vermeeren, Rivero and Conte did reach a partially different conclusion. They identified three main gaps. The first is the need for more methods focusing on qualitative data, as these could help to improve software. Further, they identified a need for methods to analyze usage of a product over-time and on different platforms (mobile, laptop). Finally, they concluded that new, simple methods that do not depend on expensive equipment are needed. [9].

Another perspective of UX research methods comes from Christoph Rohrer. He distinguishes the methods in three main dimensions. Attitudinal vs. behavioural, qualitative vs. quantitative and the context of use of a research method. The main difference to the categorization of Rivero and Conte is the focus on the scope of the method. Rohrer utilizes the classification of the results (attitudinal vs. behavioural) to simplify the selection process of a given method. Hereby methods classified as attitudinal refer to the attitude of user towards a product. Whereas behavioural methods try to describe a user's behaviour. Rohrer used this framework to classify 20 methods, which have been commonly used as part of research projects of the Nielsen Norman Group. [11]

### 2.3 Current State of Research regarding the UX of PLM Systems

This paper utilizes the definition of PLM coined by Terzi et al. They describe three main elements of PLM. These three elements are the ICT (tools, standards, and architectures), the processes (human actors, skills, and organisation) and methodologies (practices, procedures). These three main elements guide a product through the three main phases of its lifecycle. Hereby Terzi et al. distinguished between beginning, mid and end of life. Throughout the lifecycle all three main elements may change. This means that different ICT, processes and methodologies are used depending on the stage of the lifecycle [12]. This paper focuses on the UX of the employees, managing a product throughout its lifecycle. Certain aspects of the UX of PLM environments have been analyzed in the past.

One key factor in understanding the current state of UX in PLM environments is user satisfaction. Brown conducted a survey among 500 users in 2015. Surveying them about their satisfaction with the PLM tools. The results do not show a clear-cut picture. Overall, the level of satisfaction varies strongly. One finding of the study is, that satisfaction depends on the role within the organisation. Hereby differences between management and design engineers as well as differences between recipients of information (e.g. manufacturing) and design engineers have been reported. The design engineers were the least satisfied with their tools. Another finding from the study is that people who use the products more frequently tend to be more satisfied with overall usage. When asked what should be changed, the most common response was "ease of use". This indicates that users feel that their tools should be simplified. The participants were recruited via direct e-mail, social media, and online postings. The participants have a varying level of experience, the size and industrial sectors of the companies they work for varies, as well as their cultural background. These factors have not been analyzed in-depth as part of the study. [1] Another analysis of an ICT-tool used for PLM was carried out by Saenz et al. The authors set out to investigate the current state of UX in a Fortune 500 industrial company. The result was obtained using three main steps. In the first, an initial survey was carried out (participants: 24). In the next step, contextual inquiries to a selected group of engineers were made. The final step consisted of in-depth interviews. In the first phase 24 participants have been recorded in the second and third 9. On the base of their analysis the authors proposed 9 guidelines for improvement [13]. To improve the usability of PLM products, De Pinel et al. proposed an approach which would integrate UX in an agile model and add usability metrics to the

product development process of ICT tools used for PLM. This improved process is based on findings from user-centred design as well as methods used for agile software development [14]

Certain aspects of UX have been utilized in maturity models. Kärkkäinen and Silventoinen analyzed and categorized different maturity models. In their work, they describe PLM as consisting of people, processes, and IT. According to their analysis, certain maturity models focus stronger on the "softer capabilities" of PLM. These models can be seen as relevant for analyzing the UX of the PLM environment. Because these models evaluate the human interaction with PLM systems. [15]

### 3 Methodology of this paper

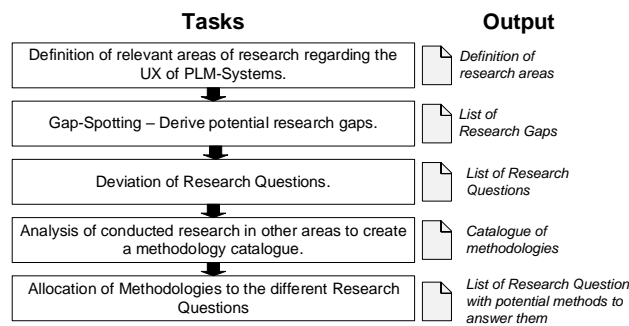


Fig. 4. Chosen Research Approach

#### 3.1 Methodology to find relevant Research Objects

The described UX models of Thüring and Mahlke, and Bongard-Blanchy and Bourcad have been used to define relevant research areas. These areas have been selected on the basis of the key question of whether or not a particular aspect of UX is specific to PLM systems.

This can be broken down to the key question: Is the component of UX influenced by the fact that that it is a PLM systems?

**Example 1:** The way a person perceives, and processes information may be relevant for the UX when it comes to PLM systems. However, the fact that a person is using a PLM system does not change the way of perception and processing. Thus, the results from experiments in a more general domain are applicable for PLM products.

**Example 2:** The user characteristics influence the UX. PLM environments are highly specialized setups and restricted to certain domains. Therefore, it is assumed that the user group and user characteristics are different from other domains and experiments.



### 3.2 Methodology to define Research Gaps.

A literature search was carried out for all research areas. The following journals, databases and search engines have been used to conduct the literature search:

- IFIP International Conference on Product Lifecycle Management
- International Journal of Product Lifecycle Management
- **Search Engines:** Web of Science, Google Scholar, and Swisscovery

The Journals have been selected because of their relevance to the topic and their scope. They represent an extension to the search conducted with the search engines.

The following criteria have been used to define results as relevant for the task at hand:

- Date of publication: Not older than 25 years
- Type of publication: Peer-Reviewed Journal / Conference Papers

### 3.3 Methodology to find and allocate suitable research approaches.

Conducting a literature search on the status of current research on the methodologies used in UX was evaluated. The following databases, search engines, conferences and journals have been used:

- Human Factors in Computing Systems
- International Conference on Human-Computer Interaction
- ACM Transactions on Computer-Human Interaction
- **Search Engines:** Web of Science, Google Scholar, and Swisscovery

The Journals have been selected because of their relevance to the topic and their scope. They represent an extension to the search conducted with the search engines.

The following criteria have been used to define results as relevant for the task at hand:

- Date of publication: Not older than 25 years
- Type of Publication: Peer-Reviewed Journal / Conference Papers / Scientific Literature
  - A method was defined as suitable if the same or a similar scientific question has been answered for a different product / domain.

## 4 Results

### 4.1 Relevant Research Objects regarding the UX of PLM-Systems

Table 2 lists the identified research objects and gives a brief introduction to their scope. Every research object has a unique ID.

**Table 2.** The seven selected research objects

ID	Research Object	Description
01	User Characteristics	Characterization of the user regarding his demographical, educational, and other traits.
02	User Reaction	Users reaction to the usage of a system..
03	Context of Usage	The environments and settings in which a product is used.
04	Processing of input	The way a system processes user input.
05	Product Characteristics	The unique traits of a product.
06	Products Reaction	The system's responses to a certain input.
07	Temporal Aspects	The changes of all components of the UX over time.

### 4.2 Found Research Gaps

Table 3 gives an overview of the research gaps that are found. Every gap is linked to a research object and describes a PLM specific issue.

**Table 3.** Found Research Gaps

ID	Research Object	Description of the gap
01	User Characteristics	Characterization of the user of an ICT-tool in a PLM environment.
02	User Reaction	Analysis of the reaction of User to the usage of PLM systems.
03	Context of Usage	The environments and settings in which ICT-tools of a PLM environment are used.
04	Processing of input	The way a PLM systems processes users input including the UX considerations during the processing.
05	Product Characteristics	The unique traits of the ICT-tools of PLM environments influencing the UX.
06	Products Reaction	The responses of a system to a certain input including the adaptation to the users' needs.
07	Temporal Aspects	The changes of all components of the UX over time, in respect to the tools used in a PLM environment.

### 4.3 Deviated Research Questions

Fig. 5 shows the 23 research questions found and their dependencies. The colors visualize the research objects and correspond to the gaps.

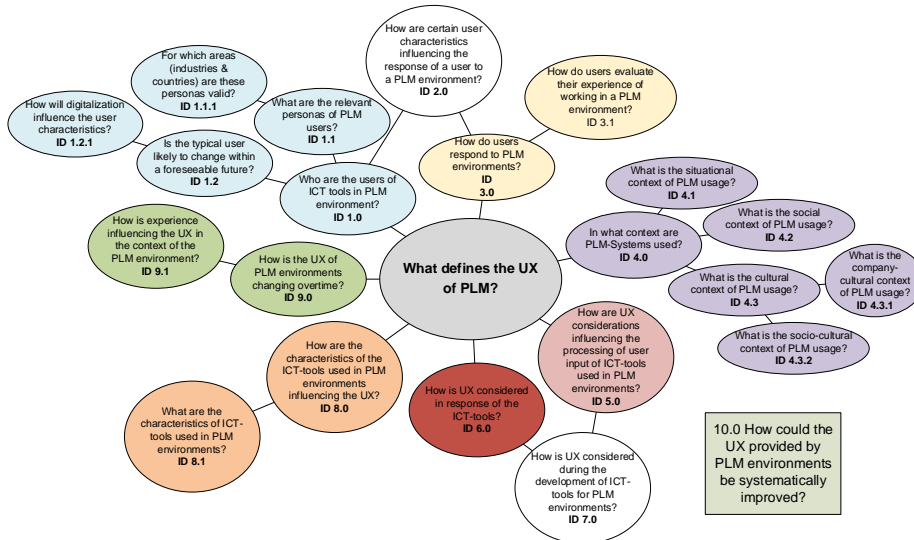


Fig. 5. Deviated Research Questions

### 4.4 Methodologies used in UX research

In Table 4 the selected high level research methods are shown. These are categorized according to the framework of the Rivero and Conte. [9] The selection of methods is based on the proposed general methods of Rohrer [11]. Some methods may be applied in a lab or a in the (Location). However, in some cases the methods have been developed for a certain location. In these cases, the secondary location is displayed in brackets. Meaning, one could utilize the methods in that location as well, but the commonly used approach would the other one.

Table 4. Methods to analyze the context of usage and the user's characteristics and responses.

M-ID	Focus area	Approach	Tech.	Information Source	Location
01	Generic	Interviews	Written Oral	Users, Developers UX-Experts PLM-Experts	Lab Field
02	Generic	Surveys	Written	Users, Developers UX-Experts PLM-Experts	Lab Field

<b>M-ID</b>	<b>Focus area</b>	<b>Approach</b>	<b>Tech.</b>	<b>Information Source</b>	<b>Location</b>
03	Generic	Focus Group	Oral	Users, Developers UX-Experts PLM-Experts	Lab (Field)
04	Attitudinal	Intercept Surveys	Oral	Users Developers	(Lab) Field
05	Attitudinal	Participatory Design	Oral	Users, Developers UX-Experts PLM-Experts	Lab Field
06	Attitudinal	User-Diary	Written	Users	Field
07	Attitudinal	Card-Sorting	Oral	Users, Developers	Lab
08	Attitudinal	Desirability Studies	Written Oral	Users, Developers	Lab Field
09	Attitudinal Behavioral	Ethnographic Field Studies	Observation	Users	Field
10	Attitudinal Behavioral	True Intent Studies	Oral	Users	Field Lab
11	Behavioral	Unmoderated panel Studies	Observation	Users	Field Lab
12	Behavioral	Unmoderated UX studies	Observation	Users	Field Lab
13	Behavioral	Moderated Usability Studies	Observation & Oral	Users	Field Lab
14	Behavioral	Usability Lab Studies	Observation	Users	Lab
15	Behavioral	Usability Benchmarking	Written	Users Developers UX-Experts PLM-Experts	Lab
16	Behavioral	Eyetracking	Observation	Users	Field Lab
17	Behavioral	Clickstream Analysis	Observation	Users	Field Lab
18	Behavioral	A/B Testing	Observation	Users	Field Lab

#### 4.5 Allocation of Methods to Research Questions

The result of the allocation process is shown in Table 5.

**Table 5.** Scientific question and proposed methods

<b>ID</b>	<b>Research Question</b>	<b>Proposed Methods</b>
1.0	Who are the users of ICT tools in PLM environments	Surveys, interviews, focus groups, ethnographic field studies
1.1	What are the relevant personas of PLM users?	Surveys, interviews, focus groups, ethnographic field studies
1.2	Is the typical user likely to change in the future?	Surveys, interviews, focus groups, ethnographic field studies
2.0	How do certain user characteristic influence the response of a user to PLM environment?	Interviews, focus group, User Diary, True Intent Studies, Ethnographic Studies, Usability Lab Studies
3.0	How do users respond to PLM environments?	Interviews, Surveys, Focus Group, User-Diary, Desirability Studies, Unmoderated panel Studies, Unmoderated UX studies, Moderated Usability Studies, Usability Lab Studies, Eye tracking
3.1	How do users evaluate their experience of working in a PLM environment?	Interviews, Surveys, Focus Group, User-Diary, Desirability Studies, Unmoderated panel Studies, Unmoderated UX studies, Moderated Usability Studies, Usability Lab Studies,
4.0	What is the context in which PLM tools are used?	Interviews, Surveys, Focus Group, User-Diary, Ethnographic Field Studies

<b>ID</b>	<b>Research Question</b>	<b>Proposed Methods</b>
4.1	What is the situational context of PLM usage?	Interviews, Surveys, Focus Group, User-Diary, Ethnographic Field Studies
4.2	What is the social context of PLM usage?	Interviews, Surveys, Focus Group, User-Diary, Ethnographic Field Studies
4.3	What is the overall cultural context of PLM usage?	Interviews, Surveys, Focus Group, User-Diary, Ethnographic Field Studies
4.3.1	What is the corporate culture of PLM usage?	Interviews, Surveys, Focus Group, User-Diary, Ethnographic Field Studies
4.3.2	What is the socio-cultural context of PLM usage?	Interviews, Surveys, Focus Group, User-Diary, Ethnographic Field Studies
5.0	How are UX considerations influencing the processing of input of ICT-tools used in PLM environments?	Interviews, Surveys, Focus Group, Participatory Design, Clickstream Analysis
6.0	How is UX considered in the response of the ICT-tools?	Interviews, Surveys, Focus Group, Participatory Design,
7.0	How is UX considered during the development of ICT-tools for PLM environments?	Interviews, Surveys, Focus Group, Participatory Design,
8.0	How are the characteristics of the ICT-tools used in PLM environments influencing the UX?	Surveys, Interviews, focus groups, ethnographic field studies
8.1	What are the characteristics of ICT-tools used in PLM environments?	Surveys, Interviews, focus groups, ethnographic field studies
9.0	How is the UX of PLM environments changing overtime?	Surveys, Interviews, focus groups, ethnographic field studies,
9.1	How is experience influencing the UX in the context of the PLM environment?	User-Diary, Desirability Studies, Unmoderated panel Studies, Unmoderated, UX studies, Moderated Usability Studies, Usability Lab Studies, Usability Benchmarking, Eye tracking
10.0	How could the UX provided by the PLM environments be systematically improved?	Surveys, Interviews, focus groups, Participatory, Design, Card-Sorting, Unmoderated panel Studies, Unmoderated UX studies, Moderated Usability Studies, Usability Lab Studies, Usability Benchmarking, Clickstream Analysis, A/B Testing

## 5 Discussion

With this paper we set out to find and analyze the potential research gaps of UX in PLM environments. The methodology chosen led to a number of research gaps and questions. As well as methods which would be suitable to help answering the defined questions. Our research is based on the definition of UX and different models defining UX. These models have been used in psychology and usability research. Any changes to the model or the underlying definition may lead to different results. This makes the scoping of UX crucial. UX is often applied in online marketing and for consumer products. Thus, most of the models and methods are aimed at this type of products.

One huge difference between the usage of PLM products and the usage of consumer products is the choice. The use of ICT-tools in a PLM environment is often involuntarily. Meaning that an employee in a company hardly ever gets to choose their preferred ICT-tools. Using a particular tool is simply part of the job. This certainly influences the overall UX. The used UX models take this factor into account in the context of usage. Another aspect of PLM environment is, that it is often made up of several different systems. Developed by different companies, following a different approach in user guidance. An engineer may work with a CAD, a designated tool for extended stress simulation of a components, a PLM-system, and an ERP. All these systems are only a part of the everyday UX of the engineer.

This makes research very difficult because not only can an isolated tool / GUI be optimized, but the entire system landscape needs to be considered as well. While the technical gap between them may be bridged utilizing state of the art interfaces, UX gaps may be more difficult to bridge.

There are a number of approaches available to evaluate the UX of a given tool. The selection made for the found research questions is simply an initial set of methods. It refers to methods that would be suitable but does not represent a finite set. Meaning, the proposed methods are suitable for answering the questions. However, there are a plethora of other methods that can be used to answer the proposed methods. Furthermore, the method is limited to the methods currently used in UX research. The PLM community and other research areas may propose additional methods that could help to answer the questions. A pleasant UX in a PLM environment may mean that a suitable tool supports a user as effectively and efficiently as possible. This particularly refers to the ability of a product to learn and the transparency within a product.

## 6 Conclusion

Certain aspects of UX have already been analyzed and improvements have been proposed. The full picture in terms of UX has not yet been analyzed. The isolated analysis of ICT-products used in a PLM environment, does not reflect the everyday reality of a user. We suggest to further investigate and develop methods to better understand UX in the full context of a PLM user.

The research gaps and research questions and methods described are suitable starting points to analyze one key factor of all PLM environments: the user.

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