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EVOLVING A VALIDATION SESSION WITH TECHNOLOGY PROBE TECHNIQUE TO SUPPORT THE ENGINEERING OF CONTEMPORARY SOFTWARE SYSTEMS

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EVOLUINDO UMA TÉCNICA DE SESSÕES DE VALIDAÇÃO COM TECHNOLOGY PROBE PARA APOIAR A ENGENHARIA DE SISTEMAS DE SOFTWARE CONTEMPORÂNEOS

Larissa Monteiro da Fonseca Galeno

Maio/2025

Orientador: Guilherme Horta Travassos

Programa: Engenharia de Sistemas e Computação

O desenvolvimento de sistemas de software contemporâneos apresenta diversos desafios, entre eles, a interação com potenciais clientes e usuários. A ausência desse contato pode dificultar tanto a especificação adequada do produto quanto sua avaliação. Neste sentido, esta dissertação propõe uma abordagem para integrar os usuários ao processo de desenvolvimento por meio de sessões de validação baseadas na técnica de *Technology Probe* (TP). Para isso, foi evoluída a técnica *ESE-TechProbe*, previamente desenvolvida e utilizada nos projetos do Grupo de Engenharia de Software Experimental da Coppe/UFRJ. A análise das versões anteriores da *ESE-TechProbe* e suas experiências de aplicação, juntamente com a observação do estado da arte sob o uso de *Technology Probe* na engenharia de software por meio de um estudo secundário, permitiram identificar as práticas que deveriam ser mantidas e oportunidades de melhoria na técnica. Assim, este trabalho tem como objetivo evoluir a técnica *ESE-TechProbe*, incorporando os mecanismos obtidos na observação do estado da arte. A intenção é tornar disponível uma tecnologia de software que possa auxiliar engenheiros de software e profissionais da prática na condução de sessões de validação com *Technology Probe* em projetos de sistemas de software. Ao final, foram sistematizadas as mudanças necessárias para a evolução da técnica, incluindo: a definição de um processo estruturado, instrumentos para capturar reações dos usuários e mecanismos de apoio para os pesquisadores envolvidos. Entretanto, apesar de sua evolução ter sido apoiada por evidências obtidas das experiências de utilização e dos resultados de um estudo secundário, análises experimentais são necessárias para fortalecer a confiança na viabilidade de utilização da *ESE-TechPobe*.

Abstract of Dissertation presented to COPPE/UFRJ as a partial fulfillment of the requirements for the degree of Master of Science (M.Sc.)

EVOLVING A VALIDATION SESSION WITH TECHNOLOGY PROBE TECHNIQUE TO SUPPORT THE ENGINEERING OF CONTEMPORARY SOFTWARE SYSTEMS

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Developing contemporary software systems presents several challenges, including interaction with potential clients and users. The absence of this contact can hinder both the proper specification of the product and its evaluation. This dissertation proposes integrating users into the development process through validation sessions based on the Technology Probe (TP) technique. To achieve this, the ESE-TechProbe technique—previously developed and used in projects by the Experimental Software Engineering Group at Coppe/UFRJ—was evolved. The analysis of previous versions of ESE-TechProbe and their application experiences, along with a review of the state of the art in the use of Technology Probe in software engineering (conducted through a secondary study), enabled the identification of practices worth retaining and opportunities for improvement in the technique. Thus, this work aims to evolve the ESE-TechProbe technique by maintaining practices that demonstrate viability and incorporating mechanisms derived from state-of-the-art analysis that are recognized as appropriate for using TP. The goal is to provide software technology that supports software engineers and practitioners conducting validation sessions using Technology Probe in software system projects. In the end, the necessary changes for the technique's evolution were systematized, including the definition of a structured process, tools to capture users' reactions, and support mechanisms for the involved researchers. However, although the evolution of the technique was based on evidence from prior application experiences and the results of the secondary study, experimental analyses are still required to strengthen confidence in the viability of the ESE-TechProbe usage.

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Chapter 1

Introduction

This chapter outlines the motivations behind this research, defining the problem it addresses, the research questions it answers, and its objectives. It presents the concept of Technology Probe, which is the main definition of this dissertation. Additionally, it provides an overview of the research design, summarizing this research's contributions to the software engineering community.

1.1 Context and Motivation

The development of contemporary software systems (CSS) is surrounded by challenges, such as being unable to access clients to build the systems specifications, not having precise requirements, and difficulty in assessing user experiences, as the interaction with contemporary software systems is different from traditional software (MOTTA *et al.*, 2018). Therefore, strategies to mitigate these challenges are being researched or adapted from the conventional software development process. One example is the lean methodology.

The lean methodology is based on the principle of the continuous improvement cycle and consists of a set of practices to help businesses understand their customers and increase product value (RIES, 2011). This methodology is widely adopted in software development, as it aligns with agile principles and enhances communication among the development team, clients, and users.

The principle of the continuous improvement cycle in software development employs an iterative and evolutionary strategy, enabling the team to validate and learn about their users throughout the development process. Consisting of validated learning cycles (also known as the learn cycle, build-measure-learn loop, or continuous experimentation with customers), it enables the team to experiment with ideas and proposals with users, learning and evolving the product based on their feedback to build a meaningful software product (COLE, 2002). Hence, validated learning cycles aim to gather qualitative user feedback that is difficult to obtain through traditional methods, such as user observation or surveys. In this sense, face-to-face validation sessions (VS) with prospective users can support the validated learning cycles (LINDGREN and MÜNCH, 2015).

A qualitative validation session fosters prospective users' interaction with a proposed software-based product. Typically conducted within a validated learning cycle, it collects data and supports the evaluation of the product. This validation session aims to achieve the following goals: learn about the user experience, understand the user's attitudes toward the product, conduct field testing, and gather ideas. By deepening the understanding of user needs and expectations, validation sessions help reduce the risk of investing in unnecessary features or products. However, observations indicate that validation sessions are often ad hoc, lacking a structured technique or method (SUTCLIFFE and SAWYER, 2013).

Continuous experimentation and validation sessions have been increasingly applied in contexts such as traditional software development, adopting agile methodologies, and creating minimum viable products. These strategies empower development teams to build products better aligned with user needs (GUO *et al.*, 2022). Moreover, this principle presents a valuable opportunity for advancing the development of contemporary software systems.

As explored earlier, the development of CSS is surrounded by challenges, particularly uncertainties. Reaching clients and users to elicit feedback and evaluating with users to obtain their input and assess the user experience are not trivial activities. Using qualitative validation sessions in the development of CSS can be beneficial for the product, improving its quality from the user's perspective. However, performing these sessions ad-hoc poses a challenge for the team to organize and conduct them. Therefore, this research proposes using the Technology Probe to support the organization of qualitative validation sessions.

Technology Probe is a collaborative method between users and developers to create new technologies. This method requires installing a Probe (functional prototype) in the user's environment, allowing the developers to collect their perceptions and improve the Probe (HUTCHINSON *et al.*, 2003). The collected data consists of user feedback, mainly focusing on experience, functionality, and suggestions for innovation. These data are evaluated to identify opportunities for innovation, software requirements, and necessary improvements.

Although TP appears to be a promising method for co-creating technologies and evaluating software from a user's perspective, its applicability is complicated. To use Technology Probe, the researcher must develop a technique, such as defining instruments to collect and analyze data.

The use of TP in software engineering has been recent, as this method was introduced in 2003 by Hutchinson (Hutchinson, 2003), and it has since been employed to support the development of products. Research that seeks to organize this knowledge produced throughout the years is valuable to the research community. Additionally, the proposal of a technique can facilitate the use of the TP method. Integrating users into the development of contemporary software systems is extremely important for building intuitive and significant systems that benefit both the user and society. Therefore, this work intends to organize the current knowledge regarding Technology Probes and evolve a technique for software engineering practitioners to apply the TP method to their studies.

The starting point of this research was an already developed TP technique, the ESE-TechProbe, tailored in the Experimental Software Engineering Group at the Universidade Federal do Rio de Janeiro (UFRJ) . Based on past experiences with the ESE-TechProbe, opportunities for improvement were identified, and this research aims to further develop this technique. Ultimately, it aims to deliver a renewed ESE-TechProbe.

1.2 Technology Probe

Exploring user interactions and behaviors in real-world settings has long been a crucial aspect of evaluating, designing, and developing software products. This section aims to provide a comprehensive overview of Technology Probe, a key concept for this dissertation. First, explore the foundational idea of Cultural Probe to delve into the concept of Technology Probe.

1.2.1 Cultural Probe

GAVER *et al.* (1999) points out the challenge of designing without understanding local cultures. With that in mind, the Cultural Probe (CP) strategy emerges to solve this problem. CP is a design-led approach to understanding and empathizing with users' engagement with a probe (CARROLL, 2000). The probe is defined by GAVER *et al.* (2004) as "a collection of evocative tasks meant to elicit an inspirational response from people".

In this sense, the probe can be anything. GAVER *et al.* (1999) exemplifies a Cultural Probe to understand older adults in diverse communities, and the probe was a collection of artifacts, such as maps, postcards, photo albums, and a media diary. Ultimately, researchers report how the probe helped establish a conversation with the local community and comprehend their needs.

In summary, a Cultural Probe is a user-centered design strategy that engages end-users with probes, inspiring them to share their experiences and realities. This approach helps understand their needs, ultimately enabling the design of more valuable and relevant solutions. An advantage of this strategy, beyond fostering a connection with users, is its ability to embrace uncertainty. Cultural Probes enable the mapping of such environments, enriching the design process. As GAVER *et al.* (2004) note, "Probes embodied an approach to design that recognizes and embraces the notion that knowledge has limits. It's an approach that values uncertainty, play, exploration, and subjective interpretation to deal with those limits.

1.2.2 Technology Probe

HUTCHINSON *et al.* (2003) reports the development of technology to support communication. In this research, the authors highlight the need to comprehend the target audience's needs (their end-users). Considering this, they used methods such as participatory design and cultural probes. Although Cultural Probe inspired end-users to reflect on their daily routine and to share experiences with researchers to develop the solution, the aspect of technology was still missing. This way, Technology Probe was a necessary concept for this project.

Technology Probe is a participatory design approach that involves co-creating technology with users. It uses a probe to inspire users to reflect on using specific technologies in their routine (HUTCHINSON *et al.*, 2003). In this scenario, the probe is a simple technological instrument used to understand the unknown, such as the desires and challenges of users. In addition, the probe should be functional for users to interact with it, yet flexible enough to encourage them to reinterpret and use it in unexpected ways. While the probe is in use, there should be a logging for researchers to comprehend usage patterns and generate new ideas for the technology.

Although the technological nature of TP, the method still balances three different aspects when applied: social, engineering, and design (HUTCHINSON *et al.*, 2003):

- **Social Aspect**: aims to collect and understand user behaviors and technology usage in a real-world setting.
- **Engineering Aspect**: reflects the probe's proper functioning; probes must work in a real-world setting where the user is settled.
- **Design Aspect**: aims to inspire users to co-create with the probe, posing their experiences and needs.

Technology Probe is similar to Cultural Probe in that it uses a probe to inspire people to reflect on their lives. In both methods, researchers observe end-users interacting with the probe. However, the TP's probe takes shape as a technology artifact. Another difference between the methods is that the Cultural Probe usually involves a single activity at a specific time. In contrast, the Technology Probe involves installing the technology in the end-user's real-world context and observing it over time.

Commonly, the term "probe" gets confused with "prototype", but regarding its definitions, the probe is the simplest technological solution used at the beginning of the project to represent the product, used prior to the prototype to assess the users' opinions and enable the co-creation. As mentioned by HUTCHINSON *et al.* (2003) "probe is an instrument that is deployed to find out about the unknown - to hopefully return with useful or interesting data". This matter about the unknown aligns with the necessity seen in contemporary software engineering. It is an opportunity to apply the TP method when developing contemporary solutions.

Although it is a promising method to mitigate the uncertainties of CSS development, the difficulty of using TP must be highlighted. The experience of applying TP can be challenging and exhausting for the software engineer practitioner, as it relies on them to develop a technique, propose activities for the study session, and select the instruments to be used for assessment of the probe. Therefore, this research focuses on developing and presenting a structured TP technique based on previous techniques already developed in the ESE laboratory. This technique has its first version designed to solve the problem of the Delta organization.

1.2.3 Delta Organization Case

Delta is a startup that delivers environmental intelligence solutions by integrating software and hardware devices. Its main product comprises web and mobile applications, sensors, actuators, a central communication unit with a biometric reader, and audio and video recording devices. These components are integrated to enable event sensing, control electronic devices (on/off states), and collect and visualize environmental data where the system is deployed.

A key objective of the proposed product is to enable prospective users to configure and operate the devices and software without requiring detailed instructions. The system must be intuitive and self-explanatory, designed to meet the expectations of non-technical users accustomed to Internet-based systems and mobile technologies. Although the product had some initial users, uncertainties remained regarding the relevance of the domain problem, the appropriateness of the proposed solution, and the usage scenarios, as its features were primarily based on the Delta founder's personal vision of an innovation opportunity.

To build an intuitive product for users and understand usage scenarios, the Delta organization requested support from the ESE Group in assessing the product's UX, evaluating the software's understandability for new customers, and identifying new usage scenarios.

Considering the presented scenario and the Delta Organization's demands, the ESE Group used a qualitative validation session with Technology Probe. The VS aims to learn about the user experience, understand users' attitudes toward the product, conduct field testing, and collect ideas that align with the organization's needs. Additionally, TP considers three perspectives: social, engineering, and design, which align with the VS and the organization's objectives.

Regarding the three perspectives of the TP, it is possible to organize what to observe in alignment with the VS and Delta goals. Considering the data required to gather, designing a set of instruments and steps to follow for conducting the validation session was feasible. Table 1.1 presents the relation between TP, the goals, and the data necessary to collect.

Table 1.1: Validation and Delta's Goals are organized in TP Perspective

TP	**Goals**	**What to observe**
Social	Learn about the UX	Prospective users' emotional reactions.
Social	Learn about the User Attitude towards the probe	Prospective users' beliefs about the product and emotional reactions.
Engineering	Field Testing	Product feature failures.
Design	Collect ideas	Prospective users' ideas.
Social	Learn about the product's understandability	Prospective users' beliefs about the product. Mistakenly or unexpected use of the features by the prospective user.
Design	Collect usage scenario ideas	Prospective users' ideas.

Focusing on the data the researcher needed to collect, instruments were developed to assess users' emotions, perceptions, and ideas. Additionally, the validation session was observed to capture product failures, thereby fulfilling the engineering aspect. This organization led to the development of the first version of the ESE-TechProbe technique.

One session was facilitated, and prospective users were present. The session lasted one hour, and the probe (an initial product version) was installed in the laboratory for the users to interact with and explore properly.

The session followed a couple of steps to fulfill the intended goals. The first step was to provide the participants (prospective users of the product) with an overview of the instruments and activities of the session, followed by an exposure to the product and allowing some time for the users to explore it. Following this exploration, it would be necessary to ask users for their opinions and capture their reactions. Then, participants are asked to choose from a predefined set of adjectives to characterize the product and record their beliefs regarding the product. Finally, participants will be asked to suggest the product's usage scenarios and ideas for the product.

The results of this session helped researchers fulfill the Delta Organization's demand by generating a report with feedback, suggestions for improving the UX, and new usage scenarios. In addition to the organization's results, the researchers identified opportunities to strengthen the ESE-TechProbe, and the lessons learned informed subsequent studies to evaluate the instruments, ultimately supporting this dissertation.

To sum up, the Delta Organization case in 2018 represents the beginning of the ESE-TechProbe, motivating this research to understand the body of knowledge of TP and proposing an evolved version of the technique. Chapter 3 will detail the first version used in Delta's case and explore other versions that preceded this dissertation.

1.3 Problem Definition and Research Question

As reported in the research of MOTTA *et al.* (2018), the development of CSS faces numerous challenges. This work employs the TP methodology to mitigate uncertainty, as it is challenging to contact and communicate with clients and users to specify the software. Technology Probe is an open methodology, which means the researcher can choose how to apply the method and tailor its technique. Although this represents a positive aspect of the methodology, it could be exhausting and confusing for a development team to use the TP in their studies. Not having pre-defined steps, instruments, clearly stated goals, and knowing what to expect from the technique can be confounding, leading practitioners to avoid using TP.

In the ESE Group, an elaborated technique underwent various versions to be applied in other contexts, as seen in the Delta Organization case. Its use opened up possibilities for improvements of the technique itself. Additionally, it was perceived that none of the versions of the ESE-TechProbe systematically compared and contrasted the techniques and findings with those reported in the scientific literature on Technology Probe.

In this sense, this research presents the evolution of the ESE-TechProbe, proposing a structured and grounded Technology Probe technique for software engineers. It will demonstrate an organized technique, with clear steps and tools to support and enhance the software engineers' experience using the Technology Probe. Therefore, the main research question of this dissertation is formulated as follows:

> ***What improvements observed in the state of the art can be introduced into an existing Technology Probe technique to support validation sessions of contemporary software systems products?***

1.4 Goal

This work aims to deliver an enhanced ESE-TechProbe technique for qualitative validation sessions, supporting the development of contemporary software systems. In this evolution, the technique is being organized to be applied in CSS contexts, especially where it isn't easy to meet with clients to elicit requirements. Ultimately, it is expected to present an experimental package for researchers to utilize the renewed ESE-TechProbe in the development of technologies.

1.5 Investigation Design

To achieve the goal of the present work, some steps were followed thoroughly. As the ESE-TechProbe was initially organized and used, the starting point of this research is to evolve and observe the applied technique and understand aspects for improvement of the process. To achieve the improved ESE-TechProbe technique, it was necessary first to understand the state of the art of the Technology Probe and propose an evolved technique. The method has its initial step, the literature review, and follows the proposal of the improved technique. Figure 1.1 illustrates these steps, which will be detailed further.

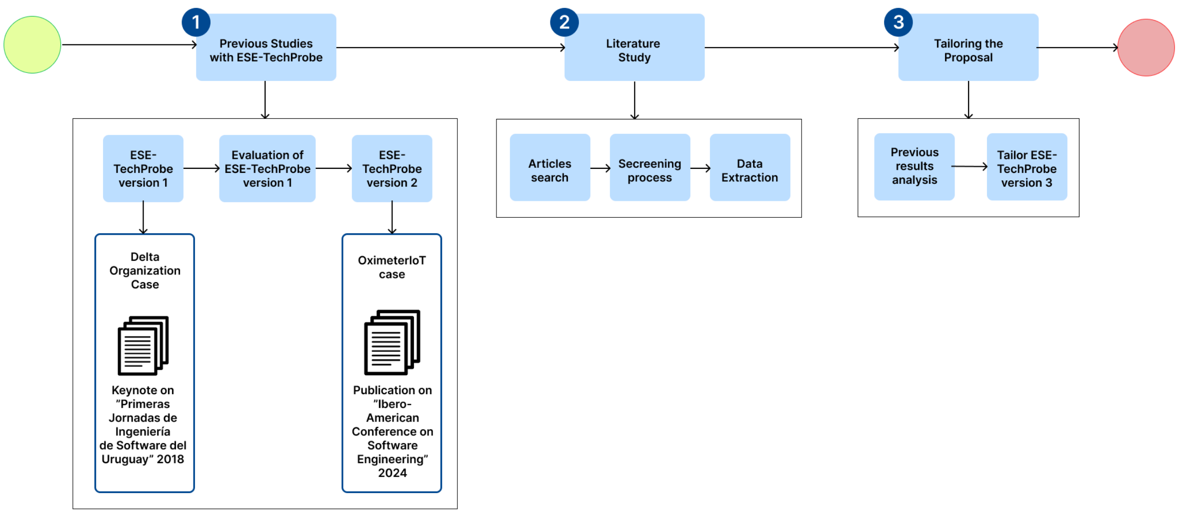


Figure 1.1: Investigation Design

1. **Previous Studies with ESE-TechProbe**: Before this research, there was the demand of the Delta Organization, which enabled the first version of the ESE-TechProbe and was presented on a keynote in 2018 at the event "Primeras Jornadas de Ingeniería de Software del Uruguay". Even before the present research, this initial version was evaluated and refined, resulting in the second version of the ESE-TechProbe used to assess the OximeterIoT. The paper published in the XXVII Ibero-American Conference on Software Engineering (CIbSE 2024) reports this experience with the OximeterIoT software system. Within the results of this

session, opportunities to further evolve the ESE-TechProbe technique, being the starting point of this research. These previous records of the ESE-TechProbe will be detailed in Chapter 3.

2. **Literature Study**: To pursue the goal of this dissertation in proposing an evolved technique, the next step was to collect evidence to suggest a third version of the ESE-TechProbe. Then, a secondary study was conducted following the Rapid Review protocol (CARTAXO *et al.*, 2018). With this result, it would be possible to understand how the ESE-Lab technique compares to other TP techniques and propose improvements based on scientific evidence. The process and results of the literature study are discussed in Chapter 4.

3. **Tailoring the Proposal**: Based on the evidence collected from the last two steps, opportunities observed in previous experiences, and knowledge gathered from the scientific literature, the next steps consist of evolving the ESE-TechProbe technique into its third version. First, an analysis comparing the evidence obtained with the current version of the technique is needed; then, a renewed ESE-TechProbe is proposed.

1.6 Contributions

Various contributions have been made throughout this research, which will be detailed in this document. The key contributions are highlighted below:

- Knowledge organization regarding the Technology Probe methodology and its use in software development, acquired through the technical literature.
- A list of desired aspects that a Technology Probe technique needs to present or keep track of.
- Proposal of a structured Technology Probe technique, developed upon the existing ESE-TechProbe and insights from the literature.
- Software practitioners and researchers will use a set of instruments to support the use of the technique.

1.7 Document Organization

This dissertation is organized into six chapters, each presenting the research results. The first chapter introduces the motivation for this research and the methodology.

Chapter 2 will present fundamental concepts essential for understanding this research, including contemporary software systems, lean methodology, user experience, and user journey. It will also display related works, primarily focusing on debating techniques for evaluating users' opinions on technology and utilizing validation sessions in the software development process.

Chapter 3 presents the ESE-TechProbe Technique and its versions throughout time. It also details previous experiences besides the Delta organization case.

Chapter 4 presents the process of the literature study conducted to support this research. It details the methodology, the results obtained, and the discussion of the analyzed studies.

Chapter 5 then focuses on exposing the proposal of this dissertation. It details the opportunities and improvements observed for the ESE-TechProbe and shows an example of the usage of the evolved technique.

Chapter 6 presents the final considerations of this research, discusses limitations and future works, and concludes this document.

Chapter 2

Theoretical Framework

This chapter presents the fundamental concepts for understanding this work, including contemporary software systems, lean methodology, user experience, and user journey. It also discusses related works pertinent to this research.

2.1 Contemporary Software Systems

The fourth industrial revolution brought new opportunities for technology. Robust and inventive solutions were needed to support smart cities and healthcare systems, which paved the way for Industry 4.0. Examples of contemporary software systems include ubiquitous systems, the Internet of Things, and cyber-physical systems. These contrast with traditional systems such as desktop, mobile, and web applications (DE SOUZA *et al.*, 2019).

As technology has advanced, society has become increasingly dependent on software-based solutions, driving the evolution of how engineers and designers conceptualize contemporary software systems (LIAO *et al.*, 2017). It's worth highlighting the challenges associated with developing CSS (MOTTA *et al.*, 2018):

- It may not be clear to understand the systems' requirements;
- It can be difficult to access stakeholders to gather specifications for the system;
- It can be challenging to understand the system's feasibility due to the employment of new technologies;
- It can be hard to assess the product's acceptability, and;
- It can be hard to assess the User Experience of the software system.

These challenges represent a risk for the development of CSS. Failing to specify the requirements correctly or assess vital aspects of a system, such as feasibility, usability, and acceptability, represents a lack of assurance that the software system may have. It is even more challenging to assess the system's quality without these aspects, for example. In this sense, these challenges suggest a research agenda for contemporary software engineering, providing an opportunity for research on innovative methods to address these challenges.

A method that can be employed to mitigate these challenges is the Technology Probe (TP). Using TP sessions to test, evaluate, and co-create probes from the end-users' perspective can benefit CSS. It is essential to highlight that a "probe" is a simple piece or representation of technology that simulates product functionalities, allowing it to be used to assess CSS. This can enable gathering ideas, collecting requirements, evaluating the user's acceptability of the product, and checking the experience the probe delivers to users. This way, TP can facilitate specifying the requirements and building a meaningful and intuitive software system for their users.

Therefore, this research aims to develop a technique based on Technology Probe, focusing on contemporary software systems. Thus, this dissertation can contribute to a possible approach for reducing risks when building CSS.

2.2 Lean Methodology and Validation Sessions

In the CSS development scenario, developing market-driven products for innovations is also an environment with high uncertainties. Under this scenario, adopting the **Lean Methodology**, which consists of an iterative and evolutionary strategy, enables the team to develop the software product following the principle of failing fast and continually learning (RIES, 2011)

The Lean methodology was proposed by RIES (2011) in the book Lean Startup. It aims to provide entrepreneurs a new way of building innovative products, focusing on customer experience, learning about their desires, necessities, and problems. Working with innovation poses numerous challenges, including uncertainty, unclear stakeholder requirements, uncertainty about whether the product will meet users' expectations, and navigating new technologies. Therefore, the Lean method follows the principle of failing fast, by testing, and learn from it. This principle was broken down into five topics: (i) entrepreneurs are everywhere, (ii) entrepreneurship is management, (iii) validated learning, (iv) innovation accounting, and (v) build-measure-learn.

The process of software development, especially the agile paradigm, leverages two of these principles: validated learning and build-measure-learn. These principles are aligned with the practice of continuous experimentation. Validated learning consists of running experiments to test assumptions about customer (or user) behavior. Build-measure-learn encourages building minimum viable products, measuring their outcomes, learn, and pivoting if needed. In essence, they highlight the process of testing the product with users and learn from this experience to improve the product through the cycle of validated learning.

This cycle involves testing ideas and proposals with users, analyzing the outcomes, refining the proposed features, and making informed decisions about the next development cycle based on the insights gained. This approach aims to reduce uncertainties about the software product, assess its acceptability, and generate new ideas for continuous development. As mentioned, the validated learning cycle encompasses a range of diverse activities, including testing with users, commonly referred to as validation sessions.

Validation Sessions facilitate user interaction with the proposed software-based product. Their primary objective is to collect user experience, feasibility, and acceptability data and ideas from the users. Validation sessions support the product evaluation and help mitigate the risk of investment loss by reducing uncertainties in the development process within a validated learning cycle.

Technology Probe and validation sessions share common goals and activities. For example, in TP, it is necessary to learn about the probe's experience; additionally, collecting ideas plays a significant role in a TP session aimed at co-creation. As presented before, TP uses three perspectives to examine the probe: social, engineering, and design. These perspectives are related to the goals of the validation session, as shown in Table 2.1.

Table 2.1: Technology Probe and Validation Sessions

TP	**Goals**
Social	User Experience
Engineering	Feasibility
Social	Acceptability
Design	Collect ideas

The Table 2.1 represents the direct relation between Technology Probe and the goals of the validation session, similar to Table 1.1, which details this relation applied to a validation session scenario, the Delta Case. This relationship opened the possibility of continuous experimentation with the Lean methodology, utilizing the Technology Probe method to support the planning and organization of validation sessions.

The described scenario of challenges in building innovative products is similar to the scenario of CSS development; they share obstacles. Therefore, applying the principle of continuous experimentation to CSS development can be beneficial. CSS development struggles with the lack of stakeholders and the uncertainties of new technologies, making it challenging to develop a minimum viable product. In this sense, the Technology Probe can support implementing the validated learning cycles in developing CSS, specifically assisting in organizing validation sessions.

This research aims to evolve the ESE-TechProbe technique, previously created in the ESE Group, for planning and executing validation sessions.

2.3 User Experience

According to NORMAN and NIELSEN (1998), **user experience** (UX) encompasses all aspects of a user's interaction with a product. It refers to a person's overall experience when interacting with a product, especially how easy, efficient, and satisfying it is. UX is concerned with the user's opinion about the product and their emotional reactions to it, whether it was intuitive to use and helped them solve a problem, or overwhelming and useless. This concept highlights the importance of aligning the product, in the context of this dissertation, specifically a software system, with the user's needs and expectations, which necessitates a thorough understanding of the user.

Understanding the user's desires, needs, problems, and profile is crucial for designing effective products. This understatement enables the team to build meaningful products with an experience that aligns with the user's necessities. Understanding the users has numerous strategies, such as personas, questionnaires, interviews, and focus groups (HINDERKS *et al.*, 2022). Another approach to supporting empathizing with the user is the user journey mapping (BRADLEY *et al.*, 2021).

A **user journey map** is the visual representation of the process a person (specific user) goes through to accomplish a goal (GIBBONS, 2018). The journey map is a user-centered approach, typically used to put into perspective every step a user needs to take to reach their objective within a system. To do this, the researcher chooses a specific type of user to design the journey (usually, there is more than one journey for the project). Primarily used as an innovation tool and to help the project team empathize with the user needs CHASANIDOU *et al.* (2015). These journeys are often utilized in the innovation process, which is necessary to identify problematic phases of product use and determine how to improve them. It helps understand the users and supports making the product specifications (BRADLEY *et al.*, 2021). Figure 2.1 shows a user journey map template.

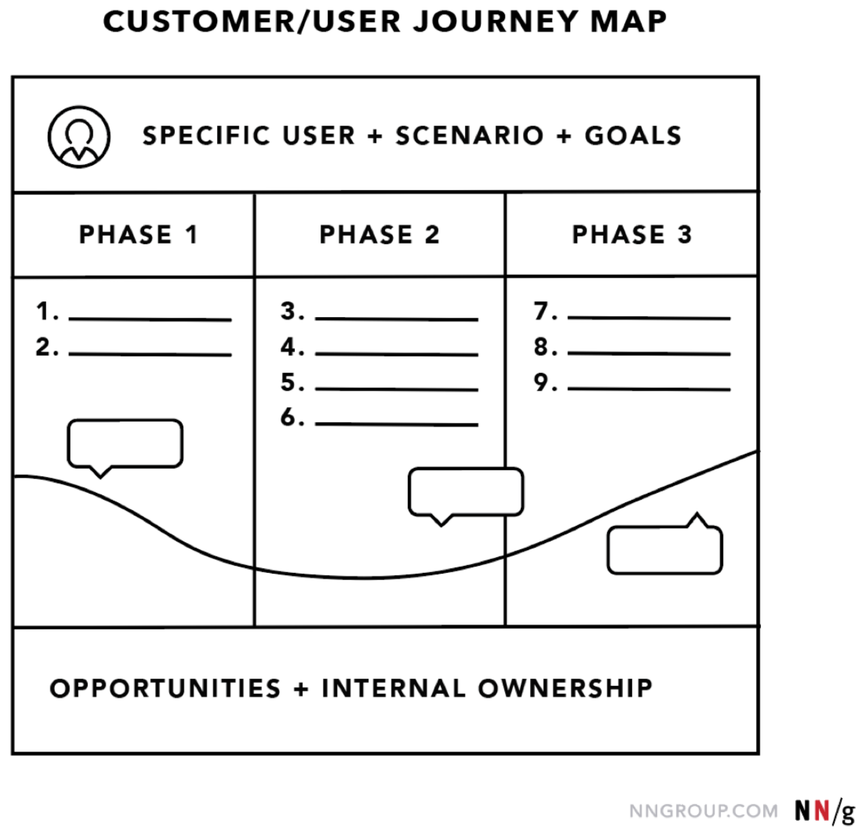


Figure 2.1: Template of User Journey (GIBBONS, 2018)

The first thing asked is the user profile, the specific user that the journey represents, the scenario in which the user is immersed, and their goals. After that come the journey phases, each step the user must go through to accomplish their goal. Also, the emotions of the user (represented by the line, if high, shows the user has a good experience in the step; it portrays that the step has a poor experience), and, sometimes, it is possible to complete it with user quotes. Finally, usually an optional part, are the opportunities for improvement for the journey, any chance to improve the user's experience.

This research uses user journey maps to conduct the validation sessions based on the Technology Probe method. The reasoning of each component is aligned: the journey map aims to help understand the user actions, as TP has the social perspective to capture user emotional reactions to the probe. Therefore, using the journey map throughout the validation session supports immersing participants in the product's usage context and allows researchers to empathize with the users.

After understanding the user, it is possible to build an initial product version, such as a probe, prototype, or minimum viable product. Regardless of the initial representation, it is essential to evaluate the user experience and assess the user's perception, feelings, and reactions. There are several ways to conduct UX evaluation, such as interviews, questionnaires, focus groups, A/B testing, and user testing (HINDERKS *et al.*, 2022).

User testing uses the end-users as subjects to evaluate the product. Evaluation sessions are organized where the end-user interacts with the prototype to be assessed, providing feedback through interviews and/or questionnaires. During the session, the researchers observe and take notes. User testing is often used with additional protocols, such as the **think-aloud protocol**, to assist the observation and data gathering. This protocol involves the user (the participant in question) sharing their opinion, perception, and feedback while interacting with the product (VAN DEN HAAK *et al.*, 2003).

To sum up, UX is present in every interaction between the end user and the product, and consists of the emotional reactions the product elicits in the end user. Certain actions, such as user comprehension and UX evaluation, are necessary to ensure a positive experience. The Technology Probe Methodology, a related concept, emphasizes observing the user experience that the probe delivers.

This dissertation focuses on the concept of Technology Probe and highlights that UX and TP share similarities and differences. The utmost significant similarity is that the TP methodology is already concerned with assessing the UX of their probes with the "social perspective." Within this perspective, TP aims to understand the user's profile, reality, needs, behaviors towards the probe, and emotional reactions—these aspects align with the concerns of User Experience.

Beyond this similarity, Technology Probe has some distinguishing features compared to UX evaluation methods, sometimes referred to as traditional Human-Computer Interaction (HCI) approaches. A typical UX strategy for assessing users begins by understanding their needs and developing a solution to test them. Technology Probe enables participatory design with users, understanding their needs and interactively developing a solution to deliver a meaningful design. Additionally, a traditional UX test would focus on the usability aspect of the solution, whereas TP is examining three different aspects of it (social, engineering, and design).

2.4 Related Work

For this dissertation, we present an evolved technique of TP to support validation sessions, gather user feedback, and aid in the development of Contemporary Software Systems. End-user feedback and contact with users during the software development process is a topic that surrounds software engineering (SE) and is a topic of interest to academia and industry, especially in the case of CSS. Also, SE is concerned with past reports of validation sessions within the software development process. Some works that address validation sessions, user evaluation methods, and their application to CCS are discussed below.

2.4.1 Continuous Experimentation and Validation Sessions in Software Development

The validation session is an activity that follows the continuous experimentation principle of the Lean methodology. Its use in software development is rising due to its opportunity to contribute to building better software systems. Therefore, some studies debate the challenges of continuous experimentation in software development, such as ANDERSON *et al.* (2022). At the same time, some go further, debating the use of continuous experimentation in CSS, as seen in SOUZA *et al.* (2023). Finally, TKALICH *et al.* (2025) discusses continuous experimentation in gathering user feedback.

The work of TKALICH *et al.* (2025) highlights the difficulties of contacting end-users to elicit requirements and applying validation techniques in a software delivery cycle. Additionally, it highlights the limitations of the literature in describing how practitioners work with user feedback in continuous experimentation environments. Then, the study interviewed 21 practitioners to capture their practices in dealing with users in continuous experimentation. They aim to explore how user necessities are implied in continuous experimentation and the related challenges of this process. The findings from this research enabled the researchers to propose a conceptual framework to guide practitioners in collecting end-user data, with a particular emphasis on the importance of being cautious when collecting excessive data. Additionally, the results suggest that practitioners utilize feedback techniques to gather user insights.

The study of ANDERSON *et al.* (2022) focuses on finding the challenges associated with continuous experimentation. Thus, it conducts a survey study with 100 practitioners regarding their perspectives on experimentation. Findings revealed that practitioners recognize the value of experimentation, since it increases the product's value, mitigates risk, and enables team alignment. However, some blockers were also identified as lacking tooling to experiment with users.

Although this research focuses on proposing a technique, rather than a tool, this technique aims to ease access to and usage of validation sessions, a continuous experimentation activity. This technique is based on the TP method, which aligns with the positive findings from ANDERSON *et al.* (2022).

Finally, the study of SOUZA *et al.* (2023) highlights the challenges of continuous experimentation in developing contemporary software systems. Due to the many difficulties already described and their impact on the quality of the CSS, this work identified an opportunity to investigate the usage of continuous experimentation. The authors conducted a literature review to find empirical studies that used continuous experimentation to develop a CSS. The analyzed studies report an opportunity for further investigation: there is a lack of technologies and concrete guidance to promote continuous experimentation in contemporary software systems.

Although the reported studies examined the broader context of continuous experimentation, this research focuses on the application of validation sessions. Additionally, the summary presented above demonstrates that the present study aligns with the challenges identified. Still, it aims to utilize the Technology Probe to help mitigate these challenges and provide a structured technique for application.

2.4.2 User Evaluation Methods and Software Engineering

The evaluation of a technology through user perception and feedback has gained increasing attention in recent years, particularly with the rise of UX. The Technology Probe method evaluates a technological product from the user's perspective, with user experience (UX) being one key aspect. In this sense, some studies discuss the use of user evaluation in the software development process: PIEDRA *et al.* (2024), ALZAYED and KHALFAN (2021), and SZABÓ and HERCEGFI (2023).

PIEDRA *et al.* (2024) conducts a tertiary study in which they synthesize knowledge from literature reviews about methods, tools, characteristics, and tendencies of evaluating usability, user experience, and accessibility of applications. Results indicate that questionnaires are broadly used to assess knowledge and usability. It was also noted that some reviews emphasize the need to evaluate UX in various application usage scenarios, particularly after long-term usage. In general, the evaluations aim to observe user satisfaction, the efficiency of the application, and its attractiveness. The study concludes that there is a gap in evaluation methods, expressing the need for more diverse methods.

ALZAYED and KHALFAN (2021) aims to understand the consequences and challenges of involving users in software development. They conducted a qualitative study and six open interviews with technology employees from a software company. The interview results show that involving users at the beginning of the development process, specifically in the conceptual stage, enables developers to empathize with users more effectively. In contrast, late-stage user involvement can create friction between the development team and user expectations. Additionally, it faced the challenge of gathering user feedback and the need to align with the goals of user-centered design when developing software.

Due to its co-creation objectives, the Technology Probe method emphasizes the importance of involving users throughout the development process, particularly in the conceptual stage, aligned with the results from ALZAYED and KHALFAN (2021). The proposed evolved technique, based on the Technology Probe, focuses on engaging users early in the development process through validation sessions. Additionally, it aligns with the interviewees' desire from ALZAYED and KHALFAN (2021) to adopt a user-centered approach.

What motivates SZABÓ and HERCEGFI (2023) to conduct their exploratory research is the lack of shared perspective between the disciplines of Software Engineering and Human-Computer Interaction (HCI) —conducting a qualitative study of UX professionals from different Hungarian companies. SZABÓ and HERCEGFI (2023) aims to complement the existing knowledge about how companies implement HCI values in the software development process. The results show that it is valid to integrate HCI values into the software engineering process to gain an advantage over product competitors. However, some precautions are needed due to the challenges of this integration. For example, it is essential to ensure that the project team is familiar with and understands the HCI methods being employed.

Although not considered a traditional HCI method, the current research aims to integrate Technology Probe, a user-centered design strategy, with the software development process. The study of SZABÓ and HERCEGFI (2023) highlights the importance of integrating methods that focus on the user in the development process. Considering the lean methodology, the team is already concerned with building meaningful products for use; in this sense, integrating TP within the validation sessions would be advantageous in creating competitive products.

The cited works examine various evaluation approaches based on end-user opinions, while also discussing the challenges of integrating user feedback into the software development process. This research proposes a technique in which user perception plays a central role in the early stages of development. The above methods can complement this technique, helping to understand user needs better.

2.4.3 User Evaluation Methods on CSS

Due to the nature of CSS, the development of contemporary software systems presents a challenge in assessing user opinions regarding their experience and usability. Several studies have already explored this field and examined opportunities for evaluating the software system from the user's perspective. This work highlights the following research: CHENG *et al.* (2024) and NTOA (2025).

The research from CHENG *et al.* (2024) aims to assess the user experience of immersive environments, specifically the metaverse, with an educational purpose. To evaluate the UX their research design consists in three significant steps: first the participant experience the immersive environment,; then the participant takes a survey, answering demographic questions and rating their overall experience with 5-point *Likert* scale; the third step consisted of interviews to get a deeper understatement of the participants answers on the survey. The study reports lessons learned regarding the experience and improvements that could be made to the UX of the proposed immersive environment.

It is worth highlighting the strategy CHENG *et al.* (2024) uses to evaluate the user experience of a non-conventional software system in immersive environments. CHENG *et al.* (2024) focused on surveys and interviews to assess participants' perceptions only after they had experienced them, not using any instrument to capture their perception while the participant was interacting with the technology. This study presents an innovative approach to evaluating the user experience (UX) of CSS, one of the dissertation's primary objectives.

The study of NTOA (2025) has the goal of reviewing user experience evaluation methods of ubiquitous systems, adaptive systems, and intelligent environments. The study searches for frameworks used to evaluate UX in these systems. It was perceived that the frameworks often look into usability (efficiency, satisfaction, and flexibility, for example); look (aesthetic of the system); content (organized navigation); emotional state (the users emotional response to the system); ubiquity (acceptance of the system); perception (perceived quality); context (socio-cultural context of the user); before use (user expectations); after use (complaints); and, actual usage (adaptation of the system).

The results presented in NTOA (2025) significantly contribute to the dissertation. Although this research aims to present a technique based on the Technology Probe methodology, which does not focus solely on UX, UX does play a significant role in the evaluation process of TP. NTOA (2025) then present essential aspects to consider when evaluating UX in intelligent systems, and some are already aligned with the current versions of the ESE-TechProbe: emotional state, with the present instruments of the technique to participate in their reaction; ubiquity of the system, being an observed aspect in the session; also the perception of the quality is observed, taking into consideration the engineering aspect of TP. The other elements, although not assessed, may represent opportunities for improvement in future versions of ESE-TechProbe.

Chapter 3

Previous ESE-TechProbe Versions

This chapter presents the ESE-TechProbe, a technique based on the Technology Probe methodology. It discusses the various versions of the technique over the years and reports on the experiences of those who have used it.

The ESE-TechProbe is a Technology Probe technique that supports validation sessions, which emerged from the demand of the Delta Organization, an enterprise interested in qualitatively assessing its products. From this demand, a technique was tailored to fulfill its needs, and it was seen as an opportunity to improve and expand this technique to other usage scenarios, especially those involving uncertainties, such as contemporary software system development.

Therefore, the first version was developed in 2018 for the Delta Organization case. Next, it was evaluated and evolved to obtain a second version, which was used in 2022 to conduct a study with the OximeterIoT, a contemporary software system. This study aimed to assess and develop the version used as a starting point for this dissertation. Figure 3.1 depicts the timeline of the technique's evolution.

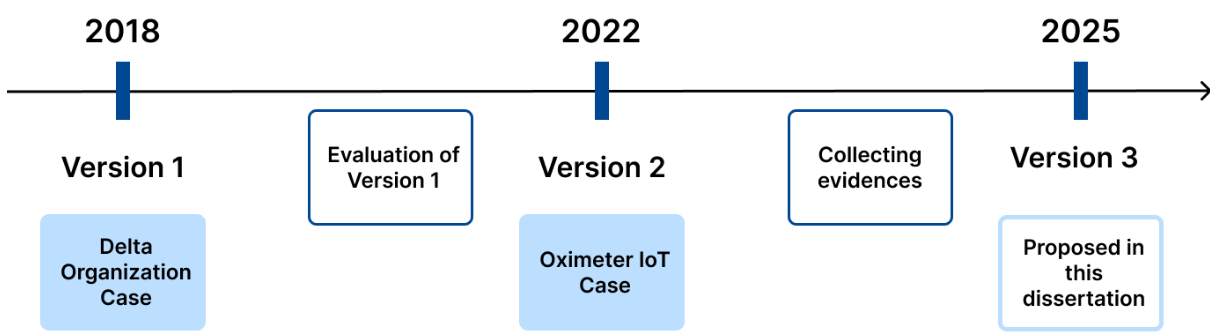


Figure 3.1: ESE-TechProbe evolution throughout the years

3.1 Version 1 (Initial)

Technology Probe supports participatory design by considering social, engineering, and design aspects, focusing on observing products in real-use scenarios and user reactions to generate rich insights. These aspects align closely with the goals of validation sessions, a step within validated learning cycles, which promote user interaction with the proposed software-based product to reduce uncertainties. Validation sessions aim to capture users' experiences and perceptions of product acceptability (social aspect) and encourage user creativity and ideation (design aspect), though the engineering aspect is less directly addressed, aside from identifying unexpected product behaviors. Table 1.1 outlines the relationship between validation session goals, TP perspectives, and the corresponding data that can be gathered.

In light of this context, the ESE-TechProbe Technique proposes organizing the evaluation session using Technology Probe and Validation Sessions, taking into account the characteristics and aspects of the Technology Probe. The session's organization using TP aims to understand user experience needs, product acceptability, field testing, and user ideation. So, observing users' emotional reactions, individual beliefs, product failures, and individual ideas is necessary.

Researchers must plan and prepare for the session when users explore and interact with the probe product. Currently, activities include deploying the probe to make it available to participants, developing the instruments that will be used, and preparing the necessary materials to conduct the session, such as colored post-its, the probe, and explanatory materials.

The instruments for the ESE-TechProbe consist of forms to comprehend the (i) social and (ii) design aspects of the TP. The user's social aspect is achieved by self-reporting their emotional reactions and beliefs. Figure 3.2 shows the instrument used to support the self-reporting. Table 3.1 lists the positive and negative adjectives the user chooses to qualify the probe, describing their beliefs. This list was based on the Microsoft Reaction Cards (BENEDEK and MINER, 2002).

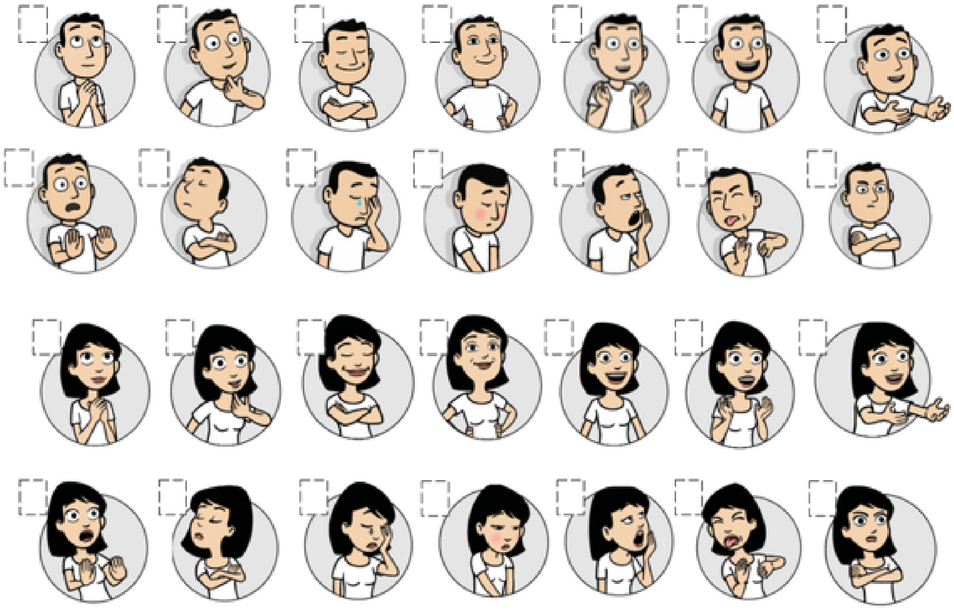


Figure 3.2: An instrument to support self-reporting emotional reactions

Table 3.1: Adjectives to support self-reporting emotional reactions

Positive	**Negative**
Accessible	Annoying
Consistent	Boring
Desirable	Confusing
Empowering	Dull
Fast	Frustrating
Helpful	Hard to use
Intuitive	Ineffective
Motivating	Old
Novel	Poor quality
Relevant	Rigid
Stimulating	Stressful
Valuable	Unattractive

These instruments focus on gathering data for the social and design perspectives of the TP, aiming to collect users' emotional reactions, beliefs, and feedback. When interested in collecting suggestions, researchers asked participants directly and asked them to report it on colored post-its. From an engineering perspective, it was done by observing the user's interaction with the probe, checking whether there would be an unexpected use of the product's feature.

Although the technique presents the components to collect the necessary data, such as smiley faces, a list of adjectives, and colored post-its, how the responsible team will incorporate these elements into their instruments relies on their discretion. This is a characteristic of the ESE-TechProbe to leave it open for the research team to adjust the technique to its necessities, only needing to incorporate the pre-defined components and follow the flow of activities. Figure 3.3 describes activities that should happen in the validation session following the ESE-TechProbe.

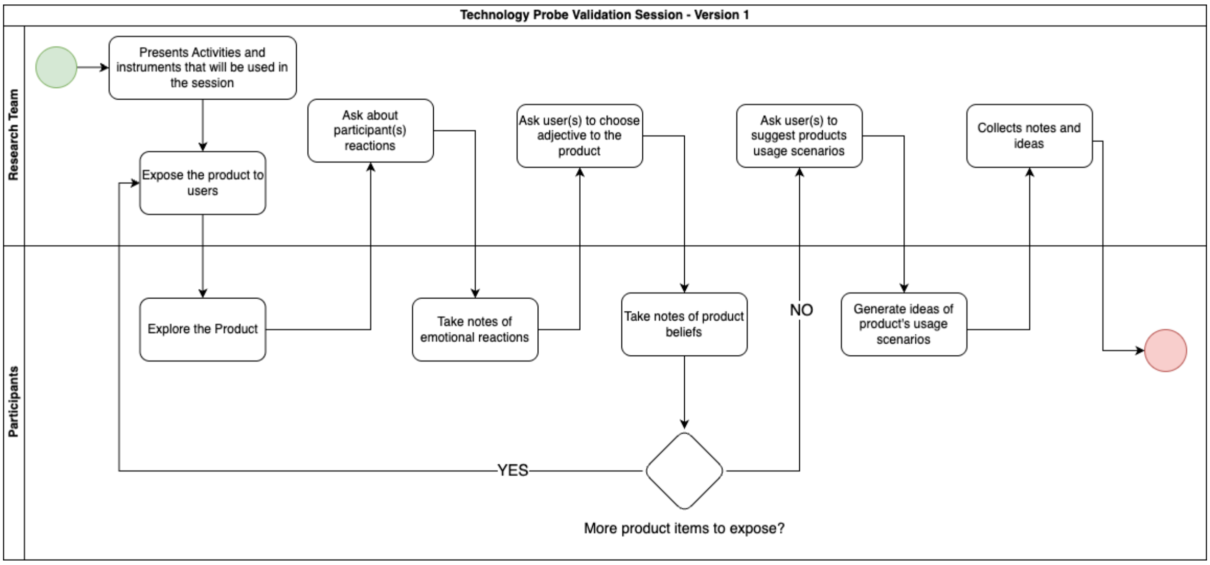


Figure 3.3: Flow of activities of ESE-TechProbe version 1

The session is structured into several steps to collect the user's perception regarding the probe. Initially, participants are introduced to the session's instruments and activities. Next, they were given time to interact freely with the product. Following this exploration phase, participants are asked to share their opinions and reactions (using the smiley faces from Figure 3.2). Subsequently, they were invited to select adjectives from a predefined list to describe the product (presented in the Table 3.1). Finally, participants were encouraged to propose potential usage scenarios and suggest new ideas for the product (using the colored post-its).

Organizing a technique to conduct validation sessions based on the Technology Probe enabled it to be applied in the Delta Organization case and obtain fruitful insights for the probe. With this experience, the opportunity arose to expand the technique used in developing software systems that are bound by uncertainties, providing an evaluation of the instruments' thinking on evolution.

3.1.1 Delta Organization Case

This case was already presented in Chapter 1, but it is important to highlight which instruments were used at which step of the session.

The Delta organization, a startup focused on environmental intelligence, has developed a system that integrates sensors, actuators, communication units, biometric readers, recording devices, and web and mobile applications. Despite having initial users, uncertainties about the system's development led Delta to seek support from the ESE group to assess UX, evaluate system understandability, and discover new usage scenarios. Validation sessions based on the Technology Probe methodology were conducted, utilizing the first version of ESE-TechProbe, which aligns these goals with TP's social, design, and engineering aspects. To capture user perceptions, tools such as facial expression charts (Figure 3.2), adjective lists (Table 3.1), and colored post-its were used.

The session's outcomes helped researchers meet the Delta Organization's needs by producing a report containing feedback, UX improvement suggestions, and new usage scenarios. Beyond addressing the organization's demands, the session also revealed opportunities to enhance the ESE-TechProbe technique. The lessons learned during this process inspired further studies on the evaluation instruments and ultimately contributed to the development of this dissertation.

3.1.2 Technique Evaluation

Two observational studies were conducted to evaluate the proposed instruments before applying the Technology Probe to assess Delta's product. To prepare for the studies, a pilot study was conducted with the ESE laboratory students. This pilot study successfully achieved the goal of the observation studies: participants interacted correctly with the instruments, expressed their emotions, qualified the product with adjectives, and wrote their perceptions on the post-its, particularly suggesting new uses for the product.

The two observational studies were organized within this result, following the ESE-TechProbe technique. Both studies followed the same procedure of the pilot study is divided into phases (illustrated in Figure 3.3: (1) explanation of the study, presenting the activities and instruments that will be used in the session; (2) exposing the product to the users and letting them explore the product; (3) ask for the user reaction (using the faces from Figure 3.2), while the researcher is taking notes; (4) ask the user to qualify the product choosing from the adjectives listed (using the instrument from the Table 3.1); and (5) ask users suggestions for new scenarios of usage (with the post its). It is essential to highlight that the researchers take notes throughout the session. This procedure was estimated to last one hour. At the end of the study, an analysis would be conducted to understand if the instruments worked as planned.

Observational Study 1 . For this study, six software engineering graduate students were recruited, representing potential users of Delta's product. A group discussion was conducted to gather their perceptions about the effectiveness of the instruments in supporting them, while also eliciting their emotional reactions and attitudes.

Throughout the session, participants expressed their opinions. Two participants said the smiley faces influenced their report of emotional reactions and, probably, their perception of the product, as one of them explained: *"I had an emotional reaction, and I identified it with some face, but then I thought that the face did not represent my ac-*

tual reaction". Regarding the adjectives board, all participants considered it very useful and found it clear how to use the instrument. Even so, they suggested organizing the adjectives into categories to ease the search, since the adjectives were only alphabetically ordered in the form. About the post-its, participants interacted with them, leaving fourteen suggestions for new usage scenarios.

Observational Study 2 . In this study, two students, one an undergraduate in computer science and the other a master's student in data engineering, represented the users of the product. As in the previous study, the aim was to collect data on the participants' perceptions of the instruments supporting them during the validation session.

About the faces, in this study, the participants commented on how they missed a smiley face that could portray a neutral emotional reaction, as one participant stated: *"It seems that I have to always be in one of the spectra: very confident or not"*. On the adjectives board, participants found it very useful, but also suggested that it would be helpful to include neutral adjectives.

Results and Discussion Both studies brought valuable feedback for the instruments used in the ESE-TechProbe technique, especially regarding the emotional reaction to the faces, since participants reported difficulty choosing one that represented their emotion. The adjectives were also a topic of discussion, especially how they are presented to the participants. Additionally, the researchers emphasize the importance of selecting the correct method when participants are asked to write down their ideas. For example, in the sessions, the first step is to present the study organization so participants know they will need to suggest new usage scenarios in the last step. Then, participants took notes of the ideas throughout the session to avoid forgetting. With these results, it is evident that there is room for improvement in the ESE-TechProbe, particularly in terms of smiley faces, adjective organization, and the overall process.

3.2 Version 2

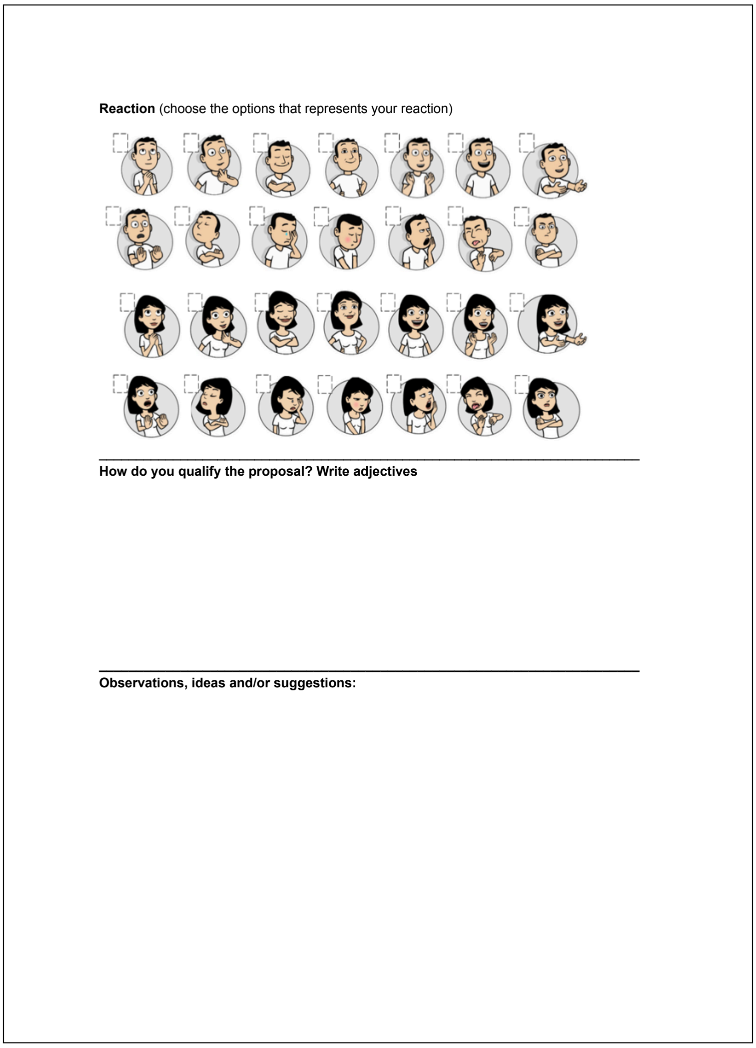
The second version of the ESE-TechProbe maintained the essence of the first version, which was still a combination of the Technology Probe with validation sessions aimed at understanding user experience, product acceptability, field testing, and ideation with users. However, not only were the improvements observed in previous experiences taken into consideration to evolve the technique, but the technique was also adjusted to meet other necessities of the researchers.

As observed in evaluating the first version of the technique, the smiley faces presented to the users could have been changed. However, researchers chose to maintain the Smiley faces Figure 3.2), since in the previous experience the Delta Organization praised this result. The, the instruments and the session process were altered to match the smiley faces better.

For the adjectives in this second version, it was preferable to leave it open for the participants to write any adjectives they felt described their reactions and emotions. Thus, in this version, a pre-defined set of adjectives is not presented, leaving it open for the participant.

Another aspect observed in the evaluations of version 1 was the process, particularly when the participant was assessed. This aspect was aligned with the ESE Group's difficulty in deploying the probe in the target environment, which led to the use of a user journey.

A user journey describes the steps a user needs to take to achieve a specific goal. For the ESE-TechProbe, the user journey would be used as support material to help immerse the participants in the usage context, enabling the simulation of product use. This way, the session is divided into the steps of the journey, guiding the participant's exploration of the probe. The steps were also used to capture the participants' intermediate reactions. By the end of each step, the user is asked to fill out a form with their emotional response and suggest new ideas. Figure 3.4 shows an example of this form.


Reaction (choose the options that represents your reaction)

How do you qualify the proposal? Write adjectives

Observations, ideas and/or suggestions:

Figure 3.4: Instrument to assess user reaction and opinion on ESE-TechProbe version 2

This form aims to capture the user's emotional reaction and feedback, and collect new ideas, aggregating these aspects into one instrument. Unlike the other version, which required colored Post-its, this version simplified the materials. This form must be used when the participant completes one step of the user journey and repeats it until the end. Figure 3.5 shows this flow of activities of version 2.

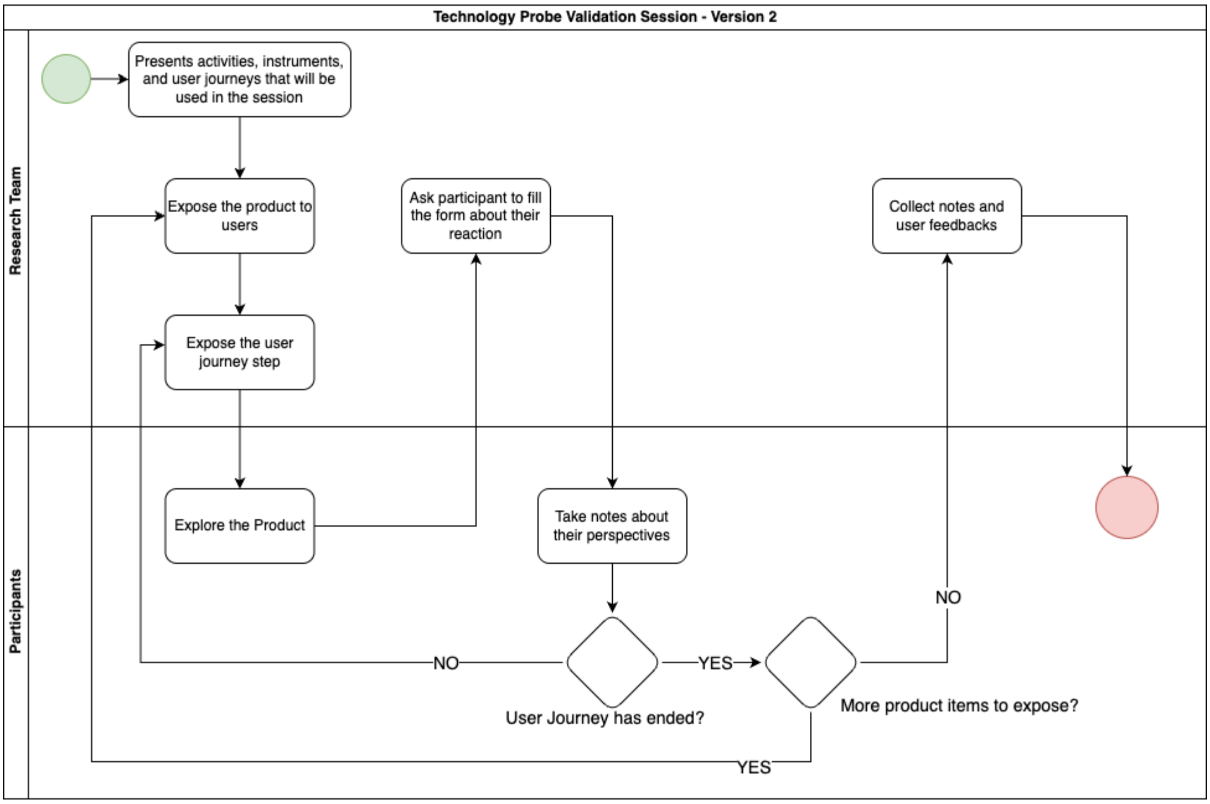


Figure 3.5: Flow of activities of ESE-TechProbe version 2

The flow of activities is similar to that of version 1 (Figure 3.3). It starts with the researcher presenting the activities, instruments, and the user journey to participants. Then, the product is presented to participants, and they begin interacting with it, following the user journey steps. By the end of each step, participants are asked to fill in the form Figure 3.4. The cycle continues until the end of the journey, and if there is no other probe, the researchers wrap up the session, taking notes on the final feedback.

It is valid to highlight that the form aims to capture the user perception, feedback, and ideas, considering Technology Probe's social and design perspectives. Regarding the engineering aspect, it is done as in the first version: observing the use of the probe and checking whether any unexpected product behavior happens.

As in the first version, some preparation is necessary before the session. For this second version, in addition to deploying the probe and adjusting the instrument to fit the study, the user journey must be designed to guide the session.

This second version enabled the validation of a healthcare software system, OximeterIoT. In this case, the user journey was crucial for immersing participants in usage scenarios, as conducting the study in a real-world setting was impossible. The results of this study revealed aspects of improving the oximeter and showed opportunities to strengthen the ESE-TechProbe technique for a new version.

3.2.1 OximeterIoT Case

The Oximeter based on Internet of Things (IoT) was a project developed for the COVID-19 pandemic; it aimed to offer a low-cost solution to hospitals to monitor patients' conditions. The ESE development team created an IoT device to collect health data from patients using sensors and publish it on a dashboard (a web application), allowing health professionals to monitor their patients' conditions. Figure 3.6 shows the IoT device, which has a bracelet on patients' wrists to monitor their conditions and a display to show it.

Figure 3.6: Oximeter Device

The development of this solution occurred through a process of continuous evolution. A couple of minimum viable products were assessed for viability. Although the development team had a healthcare professional, the solution was uncertain, especially regarding the trustworthiness of the data being collected by the sensors, the strategy to use for treating the data, and how the IoT device should be designed to provide a pleasant experience for patients. These uncertainties led the team to conduct validation sessions using the Technology Probe with the ESE-TechProbe Technique. TP would help them evaluate the solution with users, co-creating new features and understanding their needs.

Given the scenario, an oximeter was used, and due to convenience, health professionals were recruited to participate in the study. Two study sessions were organized for the user to assess the probe. Both sessions were arranged in three phases: (1) introduce the study and the oximeter, (2) use the Oximeter IoT, (3) interview.

In the first step, participants were given the context and goal of the technological proposal, and the study in which they participated was explained. At this moment, participants' expectations regarding the probe and its limitations were expected to be aligned. The second step asked the participants to engage with the probe. To assist this phase, user journeys were used to help participants focus on a specific use context. The user journey is presented in Figure 3.7.

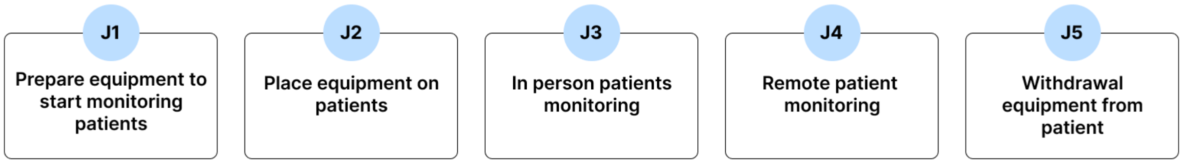


Figure 3.7: Oximeter User Journey Steps (Translated from NASCIMENTO *et al.* (2024)

Then, at this moment of the session, the participant goes through each step of the user journey, using the think-aloud protocol to express their opinions. At the end of the session, there is a questionnaire to collect participants' general perceptions about the probe, described as their emotional reactions, to understand the acceptability of the product. The questionnaire had three questions: the first one was the participant's reaction using the faces of Figure 3.2; the second was an open question for the participant to write adjectives to qualify the probe; and the third asked participants to give ideas, suggestions, or any other comment they desired.

Both studies followed this structure and used the same probe and instrument (defined in Figure 3.4). One was in a university hospital, and the other was in an emergency care unit.

University Hospital (UH) The session lasted for 50 minutes, and all four participants had the chance to manipulate the oximeters (three were brought to the session). Some adaptations were needed since there was no internet, and the mobile signal was weak, which impacted the use of the dashboard. Instead of users interacting with the dashboard, images were displayed to them. Besides this problem, the session ran smoothly; participants could discuss the solution among themselves, suggest improvements, and provide criticism.

Emergency care unit (ECU) Due to the context of an emergency care unit, the study protocol was adjusted to better suit the environment. Some parts of the study were simplified (the introduction of the session and questionnaires) to make it faster. In this case, instead of participants answering the form (Figure 3.4) at the end of each step of the user journey, they only answered at the end of the session, giving their general perception of the probe. The session lasted 30 minutes, and, as in the previous session, all participants could interact with the probe, sharing their ideas and suggestions.

Results and Discussion After both sessions, the participants' emotional reactions, ideas, and suggestions were analyzed. Results indicate no rejection for the Oximeter IoT in both cases. In the UH, expressions of curiosity and a positive reception are seen. During this session, the participants expressed their concerns and doubts regarding the data collection, device manipulation, and cleaning. The participants in the ECU showed excitement about the solution but were concerned about its usability and manufacturability. For example, they suggested having a device with batteries that would work without cables. In both sessions, curiosity was the most reported reaction.

Throughout the probe's use, participants expressed their opinions verbally. Combining this data with their answers on the questionnaires made it possible to obtain problems with the probe (pain points) and suggestions (opportunities).

The pain points were divided into three categories: (1) software, (2) manufacturing, and (3) hardware. In (1), the most expressive point is the internet dependency, which participants felt profoundly, since their workspace does not have an internet connection, representing a problem to technology usage; it was also pointed out that there is a concern about the accuracy of the data collected, notifications, and history of records. Regarding the manufacturer, the participants' primary concerns were the hygiene of the device, followed by the discomfort the probe's bracelet may introduce, as well as the potential injuries it can cause to the patient. Finally, for hardware, the necessity for a solution independent of cable appeared most as a notification on the device.

The identified opportunities align with the pain points reported by users, including the use of batteries, notifications, and a mobile application to monitor patients' conditions, as well as the collection of data through parts of the body other than the wrist.

Besides the results regarding the Oximeter IoT, the ESE-TechProbe technique was also observed. Applying a method based on Technology Probe was advantageous for the product, as it allowed the developer to comprehend user perceptions and collect their feedback. Additionally, it provided a means to immerse participants in the context of usage, allowing them to co-create and offer valuable suggestions. With the TP, gathering requirements for the proposed technology to improve the solution delivered to the users was possible. Although the technique benefited the probe's evolution, there was room for improvement regarding the method. For example, the researchers involved felt the need for instruments to assist them in taking notes and making observations throughout the session.

3.3 Conclusion

The experiences of the ESE-TechProbe technique were fruitful in putting into perspective the need to improve the TP technique. The first experience with the Delta organization was driven by market demand, which enabled the initiation of this research. Following that, it was possible to evaluate the instruments, taking into account the evolution of the technique. This evaluation ultimately yielded suggestions for areas where the technique could be improved. The second study assessed the software system, specifically the Oximeter IoT. However, besides the product's results, a third version could improve some aspects of the technique.

From these experiences, the opportunities and aspects observed to incorporate into a new version consist of:

- Evolve the smiley faces (Figure 3.2): In the first version, participants reported having trouble while choosing, which also occurred in the OximeterIoT case.
- List of adjectives (Table 3.1): In the feedback from the first version, participants said it was interesting but not well presented. In the second version, the list was not used. Still, while analyzing the results, researchers felt it would be more interesting to guide participants in choosing adjectives to characterize their experience and feelings towards the probe.
- Instrument to support researchers: The Oximeter IoT researchers missed having an instrument to guide their field notes, aligning them with the TP perspectives. Additionally, it was also seen as beneficial to have other instruments to assist researchers in using the ESE-TechProbe, thereby improving their experience with the technique.

These results motivated the present research to search for and propose a new version of the ESE-TechProbe. Thus, understanding how Technology Probe works was necessary, which led to a literature review. The evidence collected from previous versions and the results observed in the literature will inform the development of the third version of the ESE-TechProbe.

Chapter 4

Technology Probe Techniques

This chapter presents the mapped techniques of Technology Probe employed by different researchers. Following the Rapid Review protocol, a secondary study was conducted to find these techniques. The methodology and results will be detailed in the following sections.

Technology Probe is a collaborative method between users and developers to create new technologies. This method requires a Probe (functional prototype) to be installed in the user's environment, allowing the developers to collect their perceptions and improve the Probe. These collected data are evaluated regarding three aspects (HUTCHINSON *et al.*, 2003): (i) social, focusing on user interaction with the probe; (ii) engineer, focusing on the technology or manufacturing; (iii) design, identifying opportunities for innovation.

This research aims to evolve the ESE-TechProbe technique. Although some opportunities for improvement have already been identified through previous experiences, the new proposal lacks scientific evidence to support it. Considering that the technique will have its third version, it is important to consider and understand the history of TP used to evaluate technological products.

In this sense, aiming to aggregate evidence and understand the general scenario of TP, this research followed Rapid Review (CARTAXO *et al.*, 2020), which demands a strict protocol to be conducted to enable future replication. The protocol per se follows three significant steps: (i) planning, (ii) data extraction, and (iii) analysis.

4.1 Rapid Review Methodology

Rapid Review (RR) is a type of secondary study designed to provide evidence that supports decision-making for a given solution (CARTAXO *et al.*, 2020). To achieve this, RR delivers results in a shorter timeframe than a Systematic Literature Review (SLR) (TRICCO *et al.*, 2015) by streamlining specific steps of the SLR process.

This research utilized Rapid Review (RR) due to its demand to understand the state of the art of the Technology Probe and capture various techniques, practices, and usages. It was necessary to collect past evidence to propose improvements for the ESE-TechProbe, aligned with the goal of an RR. The review commenced in May 2024 and concluded in December 2024, following the protocol of the rapid review proposed by Cartaxo (2020). Before selecting the studies, several steps were taken: planning, protocol development, applying filters (by title, abstract, and full text), and, finally, data extraction. Further, the steps and results obtained will be exposed.

4.2 Planning

The planning of this second study followed the idea of the Rapid Review. It was necessary to define the essential characteristics of the research: goal, research question, sources, and the search string.

4.2.1 Goal, Problem, and Research Question

Goal

This research aims to understand how studies used the Technology Probe method to identify techniques and instruments employed for the TP.

Problem

There is no standard for applying the Technology Probe. The researcher is responsible for developing techniques (participant/user profiles, data collection instruments, etc.). Therefore, organizing knowledge regarding the TP techniques that have already been developed and used is relevant for the evolution of this method.

Research Questions

With these aspects in mind, the literature review sought to answer the following questions:

- How is Technology Probe being used to evaluate software technologies?
- What techniques or practices can support the Technology Probe in software engineering?

4.2.2 Sources and Research String

Source

Following the concept and idea of a Rapid Review, only one library was chosen to perform the search. This study will use the Scopus database, which integrates different libraries and provides diverse results from peer-reviewed scientific journals and conference proceedings.

Research String

The expression used for the search string was defined using the PICOC method (PETTICREW and ROBERTS, 2008). Table 4.1 shows how it was built.

Table 4.1: PICOC Search String

PICOC	**STRING**
Population	("software systems" OR "software engineering" OR "software" OR "systems" OR "applications" OR "solution" OR "platforms" OR "prototypes" OR "products" OR "MVP" OR "Minimum Viable Product" OR "technolog*") AND
Intervention	("technology probe" OR "lean cycle" OR "build-measure-learn" OR "continuous experimentation with customers") AND
Comparison	-
Outcome	("technique" OR "method" OR "evaluation" OR "approach" OR "process" OR "tool*" OR "procedure" OR "strategy" OR "research" OR "study")
Context	-

For the "Population," synonyms were used for "software systems" since the Technology Probe methodology affects software systems. While the "Intervention" is the Technology Probe, similar methods and approaches were used to broaden the research. It is essential to highlight that the term 'Participatory design' was initially considered, but including it would result in more than a thousand papers, making it impossible to evaluate the term within the context of a Rapid Review. Since this research does not aim to compare TP with other methods, the space for "Comparison" was left blank. Due to the aim of capturing the techniques developed to apply TP and understanding the general context in which research uses TP, the "Outcome" was filled with synonyms for technique. Finally, "Context" was also left blank because there was no search for a specific context in which TP was applied.

The Scopus search string is: TITLE-ABS-KEY (("software systems" OR "software engineering" OR "software" OR "systems" OR "applications" OR "solution" OR "platforms" OR "prototypes" OR "products" OR "mvp" OR "minimum viable product" OR "technolog*") AND ("technology probe" OR "lean cycle" OR "build-measure-learn" OR "continuous experimentation with customers") AND ("technique" OR "method" OR "evaluation" OR "approach" OR "process" OR "tool*" OR "procedure" OR "strategy" OR "research" OR "study")) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar"))

4.2.3 Criterias

Inclusion Criteria

- To discuss a Technology Probe technique;
- It is related to software technologies;
- Peer-reviewed English text, and;
- It is a primary study.

Exclusion Criteria

- Full text is not available;
- Duplicated studies;
- It is a secondary study (e.g., another rapid review);
- Do not discuss a TP technique; only replicate one, or;
- Chapter books and reviews.

4.3 Extraction Model

Some of the selected papers' data were relevant (Table 4.2) and based on the research goal (Table 4.3).

Table 4.2: Paper Data

Data	**Description**
Title	work title
Author(s)	authors name
Year	publication year
Abstract	work abstract

Table 4.3: Data based on the goal

Data	Description
Motivation	motivation to use technology probe
Probe	what was the software technology solution used
Technique	description of the technique or practice proposed in the work
Outcomes	conclusions from the Technology Probe
Advantages of the Technique (optional)	what were the advantages of using the described technique
Disadvantages of the Technique (optional)	what were the disadvantages of using the described technique

4.4 Selection Process

The selection process started in May 2024 with 263 papers from the Scopus database. In December/2024, an update was made to check whether documents from that year had already been indexed in the library. This update enabled the screening of 287 articles through the investigation. The tool chosen for this process was Google Spreadsheet, as it's easily used and facilitates collaboration. Figure 4.1 sums up the selection process.

Figure 4.1: Rapid Review Steps

The first filter used the Rapid Review Protocol, focusing on the articles' titles. Of the 287 articles, 42 were discarded, mainly because their research fields were not related to technology, and others focused on areas that were not of interest for this research. Foremost, this step aimed to exclude papers that, by their title, were perceived as not related to the software engineering field. Ultimately, it was revised by the advisor.

The following filter was applied to the abstract: 245 were started in this phase, and 111 were discarded. From these discarded studies, it was clear in their summaries that the term "Technology Probe" was used as a synonym for "Prototype," not to evaluate the probe itself, but to use some piece of technology to assess other aspects. For example, use a piece of technology in a work environment and check if collaboration improves. Others don't use the Technology Probe technique, instead relying on traditional HCI methods.

Finally, the full-text filter was applied in the remaining 134 studies. As in the previous phase, most of the articles discarded were due to misusing the term "Technology Probe" or focusing on evaluating aspects other than the probe itself. Ultimately, 42 articles were selected for data extraction.

4.4.1 Extraction Data and Synthesis

The extraction also happened in a Spreadsheet[1] following the model described in Tables 4.2 and 4.3. At the end of the extraction, a qualitative analysis was conducted following open coding and categorization. For this part, the tool QDA Miner[2] was used. Further, these results will be presented and discussed.

4.4.2 Results

The selected studies after the filtering process can be seen in the Table A.1, which provides the ID (from S1 to S42), title, authors, and year of publication for each study. A demographic and qualitative analysis was conducted with these studies, which will be detailed in further subsections.

4.5 Demographic Analysis

The demographic analysis focused on investigating relevant metadata of the studies, including the year of publication, as well as specific study aspects, such as the problem domain, probe characteristics, and observation strategies.

Figure 4.2 shows the chronological evolution of studies using Technology Probe to evaluate and develop software probes. In 2003, it was possible to see one study representing S35 (HUTCHINSON *et al.*, 2003), the study that debuted the concept of Technology Probe.

[1] `https://zenodo.org/records/15330733`
[2] `https://provalisresearch.com/products/qualitative-data-analysis-software/`

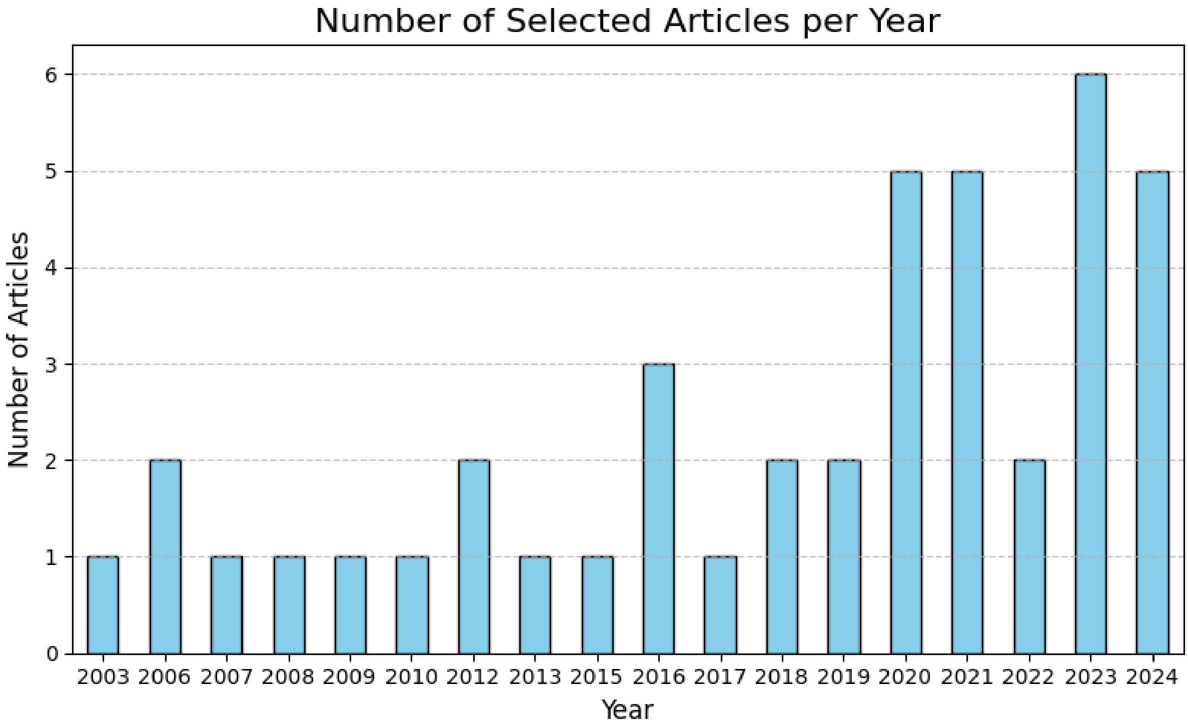


Figure 4.2: Distribution of Study per Year

Considering the study aspect, it was essential to map the distribution of the context in which the TP methodology was employed. Table 4.4 shows this arrangement. Most studies using TP are in the healthcare context, while eight problem domain categories have only one associated study: collaboration, education, farming, model comparison, music, personal safety, UX design, and wearable technology. It is valid to highlight that 'Design of Technology Probe' refers to studies that propose techniques of TP and use the TP methodology to evaluate their strategies.

Table 4.4: Problem Domains and Corresponding Studies

Problem Domain	**Studies**
Collaboration	S38
Communication	S8, S15, S20, S21, S34, S39, S42
Dance	S13, S41
Design of Technology Probe	S32, S33, S35
Education	S23
Farming	S37
Healthcare	S2, S3, S5, S6, S7, S10, S11, S16, S19, S22, S25, S26, S27, S30, S36
Model Comparison	S12
Music	S14
Personal Safety	S1
Smart Device	S9, S18, S28, S31
Smart Home	S4, S24, S29
UX Design	S40
Wearable	S17

4.6 Qualitative Analysis

The qualitative analysis consisted of two steps: open coding and categorization. It aimed to answer the research questions to characterize the usage of Technology Probe in the field of software engineering:

- How is Technology Probe being used to evaluate software technologies?
- What techniques or practices can support the Technology Probe in software engineering?

Figure 4.3 presents a summary of the categories and codes identified in the process, showing the significant result of this analysis: the characteristics of the Technology Probe study techniques. The subsequent sections will detail these categories and codes.

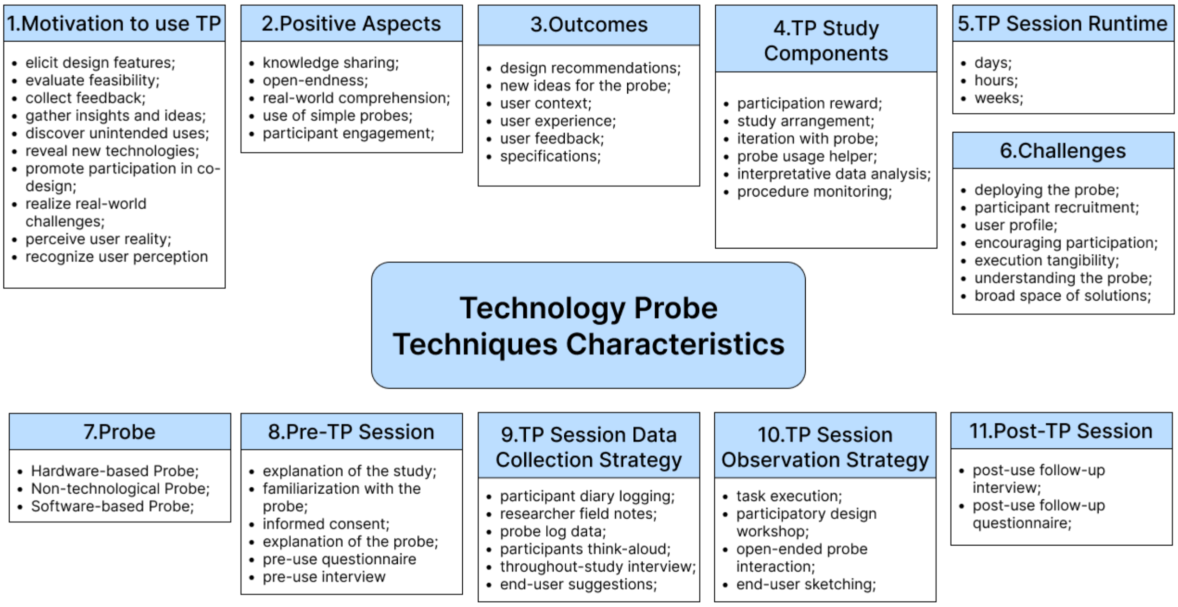


Figure 4.3: TP Techniques' Characteristics

4.6.1 Motivation to use TP

The category of "Motivation to use TP" encompasses the driving factors that led researchers to adopt the Technology Probe methodology in their studies. It captures the specific needs or research objectives that made TP an appropriate and attractive choice. Identifying these motivations enables a better understanding of TP's perceived advantages and alignment with software development practices. The Table 4.5 shows each code's arrangement and associated papers.

Table 4.5: Codes from Motivation to use the TP category

Code	Studies
elicit design features	S1, S3, S5, S9, S11, S16, S19, S27, S39, S40
evaluate feasibility	S4, S12, S15, S17, S20, S29, S32, S34, S35, S36, S40, S41, S42
collect feedback	S2, S3, S8, S9, S13
gather insights and ideas	S2, S3, S5, S7, S8, S13, S17, S19, S24, S29, S30, S31, S32, S35, S36, S37, S40
discover unintended use	S2, S8, S17, S21, S23, S37
reveal new technologies	S2, S3, S6, S7, S11, S15, S17, S18, S19, S20, S27, S34, S35, S38, S40
promote participation in co-design	S1, S2, S4, S5, S10, S11, S13, S15, S22, S23, S25, S34, S35, S37
realize real-world challenges	S1, S4, S5, S13, S17, S18, S19, S22, S23, S24, S25, S31, S34, S41
perceive user reality	S1, S3, S5, S6, S9, S11, S13, S16, S17, S18, S19, S20, S21, S23, S24, S25, S28, S30, S33, S35, S37, S39, S40, S42
recognize user perception	S3, S5, S6, S9, S12, S13, S14, S15, S16, S20, S21, S23, S25, S26, S28, S31, S33, S34, S37, S39, S40, S41, S42

The code "**elicit design features**" comprehends studies that used the TP to elicit design ideas for their product, S11 puts "the goal was to inspire design of a bespoke VR application to enrich the social connectedness of older adults living with dementia and their caregivers". Or how S3 arguments use the TP to "elicit ideas and requirements for the final product". While the code of **"gather insights and ideas"** approaches wanted to collect feedback andn S13, the researchers detail: "We chose this method for its suitability for gaining insights into how the exploratory design of MR mirror visualizations may be accepted, adopted, and appropriated by users for the complex and challenging creative process of dance and choreography".

Meanwhile, **"collect feedback"** comprehends studies that used the probe to evaluate the probe and wanted end-user feedback. S3 and S13 are studies that aimed to collect feedback and utilized the TP to elicit design features and gather insights and ideas, incorporating both perspectives.

Studies that showed the code of "evaluate feasibility" were interested in the engineering perspective of the Technology Probe methodology, using its techniques to evaluate its functionality and behaviors. To illustrate this, S20 puts, "With the technology probe, we wanted to test whether an interactive communication tool will convey an awareness of each other's daily lives and influence the communication routines of the communication partners".

The code about **"discover unintended use"** expresses the desire of researchers to consult users on their probe to look for new functionalities; for example, S23 states, "Wearables are not necessarily a "one size fits all" technology, so studying their use in an underexplored context gives new insights into their possibilities" and S37 also puts "inspire them to think of other ways of using new technologies". Similarly, the code about "reveal new technologies" also aims to explore novelty, focusing on gathering insights for innovation and thinking ahead about new products. On that, S3 describes "to identify requirements for future walking mobile applications" and S34 "inspiring users to consider how technology can enhance their environment".

Although one of the premises of TP is co-creation with users, it was seen that many studies had other motivations for employing the methodology in their research. However, some maintained the essence of the method and wanted to take advantage of the collaborative aspect of the technique to co-create the probe with their end-users, having the code associated with "promoting participation in co-design." In S10, it is possible to see that "this study looks at the co-design of a technology probe that acts as a tool to facilitate personal reflection.". Also, in S34, "engage individuals with cognitive disabilities and their family caregivers as co-designers of their remote communication system".

The code about **"realize real-world challenges"** focuses on studies that used the probe to capture environmental challenges that would affect the probe. For example, S13 says they aim to "gain insights into a wider range of situations and contextual factors of interacting with the MR mirror for dance". Similarly, S19 states they want to "gather contextual information about the environment and technology use".

The last two codes of this category are related to the user. About **"perceive user reality"** focus on using the TP to understand the context where the user is situated. Unlike the code above, this focuses on the user. On this one, S40 expresses they want to "gain insights into their (users) experiences of barriers to accessible entertainment activities in general, and theatre performances in particular".

Finally, the code about **"recognize user perception"** aggregates studies that use the methodology to understand user needs and desires, focusing on comprehending the user's reaction to the probe. S16 states, "understand users' unique experiences," and S39 also puts "understand older adults' interaction patterns in their desired experiences".

4.6.2 Positive Aspects

The category "Positive Aspects" encompasses the advantages and strengths identified in the TP techniques analyzed in this literature study. It aims to consolidate the reported benefits and highlight the particularly effective elements in applying TP across the analyzed studies. Grouping what worked well gives researchers insights into the successful practices and positive outcomes associated with the methodology. Table 4.6 sums these points.

Table 4.6: Codes from the Positive Aspects category

Code	Studies
knowledge sharing	S10
open-endness	S10
real-world comprehension	S1, S7, S35
use of simple probes	S1, S26, S32, S42
participant engagement	S7, S11, S25, S31, S32, S34, S35

The code of 'knowledge sharing' refers to studies that examine how the technique enables the exchange of knowledge and information between participants during the study. Study S10 exposes this “sharing our individual experiences with the probe in the workshop, we were able to influence each other and encourage further reflection upon how various interaction modes could enhance the translation of our narratives”. This study also reports the benefit of **“open-endness”** from the technique of TP used, S10 illustrates this aspect on “this approach offered more flexibility and open-endness for the designer participants to interact with the device, manipulate it using low-fidelity material and engage with the reflective tasks that we would provide in the probe package” referring to the fact the technique enabled diverse interactions with the probe.

The code "real-world comprehension" describes studies that reported how TP enables understanding of the context in which the probe is settled, as a benefit of the technique. For example, in S1, they say, “we found a functional prototype extremely useful in interacting with our participants: it allowed us to get to the point quickly as we tried to explain the utility of a prospective digital safe-space community, while also allowing digitally non-literate participants to comprehend how such a service would work”. Also, in S35, they report the study “provided real-life use scenarios”.

Another positive aspect is the use of simple probes. The probe in the TP methodology is a simple piece of technology, such as an implemented prototype; some studies have highlighted this as a benefit of the method. In S26, the researchers share that "an adapted technology probe approach using paper prototypes can be useful for stimulating further ideas and reflections."

While some studies report the challenge of encouraging participation, others report the contrary. The code of 'participant engagement' aggregates studies that argue how their TP technique helped evolve participants through the probe and the session. For example, S32 shares, “final advantage of our approach is that it creates a period where the users are completely engaged with the technology probe". Also, in S34, "early findings indicate that technology probes are a powerful way to connect with and empower individuals with cognitive disabilities to participate in design in a way that traditional participatory design methods cannot".

4.6.3 Outcomes

This category "Outcomes" captures the results and impacts reported by the studies as outcomes of applying the Technology Probe methodology. It aims to group the insights, discoveries, and tangible benefits that emerged from using TP, illustrating how the technique contributed to the advancement of each research project. By summarizing the outcomes, it is possible to show what researchers can expect by using the TP techniques. Table 4.7 points out the perceived outcomes.

Table 4.7: Codes from the Outcomes category

Code	Studies
design recommendations	S2, S3, S4, S5, S6, S7, S11, S17, S19, S20, S21, S22, S23, S25, S33, S35, S36, S37, S38, S40
new ideas for the probe	S2, S7, S8, S10, S11, S13, S15, S22, S24, S25, S26, S27, S29, S31, S32, S34, S41
user context	S1, S5, S6, S10, S12, S16, S17, S18, S19, S22, S23, S25, S29, S32, S36, S40, S41, S42
user experience	S1, S2, S5, S6, S11, S13, S14, S15, S16, S17, S18, S19, S21, S23, S26, S28, S29, S34, S39, S40, S41, S42
user feedback	S1, S3, S4, S5, S10, S13, S17, S23, S24, S26, S28, S31, S32, S35, S37, S38, S40, S41, S42
specifications	S1, S2, S6, S9, S11, S12, S14, S16, S17, S18, S19, S23, S27, S28, S30, S35, S39

The code of **"design recommendations"** represents studies that, based on their results, reported how the Technology Probe enabled them to achieve a set of suggestions regarding the design for future applications in the field in which the study was conducted. For example, S11 states, "the findings from this research will then inform subsequent action research cycles aimed at developing a VR application to enhance the social connectedness of older adults living with dementia". S36 also shares "set of design principles for intelligent reflection support systems that serve as inspiration for future work".

While the above code discusses future possibilities, 'new ideas for the probe' are works that have obtained insights from the current probe participants interacting. In S10, it was suggested new features, and in S15, they report “generally, we observed that both siblings suggested and got excited about ideas that would bring playful elements to communication technology”.

As the code aforementioned, **“specifications”** also refers to ideas for the solution the participants interacted with. However, it encapsulates studies that explicitly show they obtained requirements or identified features through the TP. S28 reports, “this information was then directly used to identify general use cases and derive critical technical requirements.”. Also, in S30, it was shared that “from the probe study we summarize the following requirements for improved support”. In S35, they state “reveal practical needs and playful desires within and between distributed families”.

Finally, there were identified three outcomes regarding the user: (i) **“user context”**, (ii) **“user experience”**, and (iii) **“user feedback”**. The first group studies that derive results about user characteristics, including their environment, profile, user necessities, and problems; S1 shares “these sessions were vital in understanding and creating a framework that would work for these women and their unique constraints”. The second regards results referencing the perceived experience of the participants while interacting with the probe; for example, in S39, the study revealed the user preferences for the experience to be delivered, and in S17 reports “during the semi-structured interview, participants were asked to rate their subjective experiences while wearing the device and were allowed to discuss their opinions and observations, providing deeper insights into how the design and experimental factors contributed to the user experience”. The third and final one discusses the general feedback participants provided on the probe; for example, in S37, participants reported that they found the probe helpful, whereas in S41, participants criticized specific features of the probe.

4.6.4 TP Study Components

This category of “Study Components" aims to group structural elements and methodological choices observed across studies employing Technology Probes. It groups characteristics related to how the research was designed and conducted, such as strategies for participant engagement (e.g., offering rewards), the overall study setup, methods for supporting participants during probe usage, approaches to analyzing the collected data, and mechanisms for monitoring procedures. These components reveal practices that shape TP techniques. Table 4.8 shows the distribution of the attributes in each code.

Table 4.8: Codes from the Study Components category

Code	Studies
participation reward	S4
study organization	S1, S2, S3, S5, S6, S9, S10, S11, S13, S14, S16, S17, S18, S24, S25, S34, S38, S39, S40, S41, S42
iteration with probe	S7, S8, S31
probe usage helper	S6, S10, S11, S17, S37, S40
interpretative data analysis	S23, S26, S28, S33
procedure monitoring	S6, S21, S22, S27, S40

The code **"participation reward"** explores the characteristic brought on S4, in which participants received monetary compensation. While the code **"iteration with probe"** represents the action some studies took to evolve the technological solution, the TP session was happening. It is intriguing to notice that on S8. However, it lasted for hours, and the researcher made adjustments between user interactions to evolve the probe, allowing participants to use slightly different versions.

Some studies report having a tutorial or an artifact to help users with the probe. Grouped in the code **probe usage helper**, the studies approached the matter differently. In S6, S10, S17, and S37, for example, participants were given a printout instruction packet. On the other hand, the researcher provided help in S11 and S40.

Regarding the code of **"procedure monitoring"**, there are studies in which researchers often keep in touch with participants to check their research or the probe condition. For example, in S6, they report, "occasionally we checked in with the participant to answer questions, help them use the probe, and resolve technical issues". It was similar in S27, but they also wanted to encourage participants to engage with the probe: "We maintained contact with participants and encouraged them to interact with us whenever they came across any problems or wanted to share their use, e.g., their mood, health condition".

The code of **"study organization"** aimed to group the attributes related to the organizational aspect of the studies. Articles report that some of the studies were organized in phases (e.g., S1, S2, S5, S16, S17, S24, S39, S40), For example, S5 reports using "a user-centred design process in three phases." and S17 describes the phases "The study consists of (1) a pre-survey (10 min), (2) the wearability study phase (6 hours), and (3) the post-study interview (30 min). A pre-survey collecting demographic data and participant hand-measurements was administered before the study". While some report having one-on-one sessions with participants (S1, S10, S41). S9 expresses having an iterative design process to conduct the TP study, and S25 uses a cultural probe as part of their TP study, explicating the process "involved a six-week cultural probe study [...] and interviews with 11 participants to understand their current practices in using everyday personal technologies to help them manage and improve their low self-esteem".

Finally, the code of **"interpretative data analysis"** consists of studies explicitly stating their strategy for conducting data analysis. Although most studies are expected to deal with qualitative data, only S23, S26, S28, and S33 reported their strategy. In S26, for example, they used open coding, and in S23, they developed conceptual categories and descriptive themes.

4.6.5 TP Session Runtime

This category, "TP Session Runtime", addresses the temporal aspects of Technology Probe sessions, specifically focusing on the reported duration of the user interaction with the probe (the session). By capturing the duration of participant interaction with the probe, the studies provide insights into session planning, user engagement levels, and the practical feasibility of conducting TP-based investigations within various research contexts. There are no explicit recommendations within the Technology Probe methodology; the TP time can vary as long as the user interacts with the probe. The observed techniques showed this variation, with some lasting hours, while others lasted days or even weeks. Table 4.9 shows the scenario of studies that explicitly reported their duration.

Table 4.9: Codes from the TP Session Runtime Strategy category

Code	**Studies**
hours	S1, S8, S15, S17, S32, S41, S42
days	S10, S32
weeks	S3, S4, S5, S13, S19, S20, S21, S22, S24, S25, S26, S27, S28, S29, S30, S31, S33, S34, S36, S37, S38, S40

The code **"hours"** groups studies that lasted less than a day. In general, these sessions lasted between 20 and 45 minutes (S1, S8, S15, S41), one hour (S42), or more than one hour (S17 and S32). Meanwhile, **"days"** report sessions that lasted between one day and less than a week, S10 reports two days, while S32 does not specify. Lastly, the other studies describe experiences that lasted for **"weeks"**, varying between a couple of weeks (S3, S4, S5, S20, S21, S22, S25, S26, S27, S28, S29, S30, S31, S33, S36, S37, S38, S40) or months (S13, S19, S24, S34).

4.6.6 Challenges

This category compiles the main difficulties and obstacles reported across the analyzed studies regarding using Technology Probes. By sharing these difficulties, the researcher can foresee them and craft a technique to mitigate them. Studies often failed to disclose some limitations or challenges. The Table 4.10, shows the mapped challenges from the analyzed studies.

Table 4.10: Codes from the Challenges category

Code	Studies
deploying the probe	S4, S6, S35
participant recruitment	S4, S5, S29
user profile	S1, S3, S22, S29
encouraging participation	S6, S29, S32
execution tangibility	S1, S3, S19, S22, S32, S33
understanding the probe	S6, S32
broad space of solutions	S9

The code of **"deploying the probe"** explicitly states the difficulty some studies had when making the probe available to participants. S35 comments on the risk of failure and unexpected results when deploying the technology; S6 researchers conducted studies with HCI experts anticipating possible usability issues and failure on deployment; in S4, it is reported, "In this respect, the first thing that struck us was the practical challenge of deploying the connected shower; for despite the use of low-power batteries and standard fittings, each of our participants' homes had different showers, which impacted installation of the shower components, and different layouts, which impacted communication between the shower components and local hub and required the careful mapping of wireless signal strengths to find the right location to place the hub".

Studies that reported trouble finding and recruiting participants were grouped on the code of **"participant recruitment"**. S4 shares their difficulty finding participants who meet the technical requirements, "participating households must have a non-electronic shower so that our researchers could install the connected shower." S5 and S29 report challenges within the sample size and context constraints, impacting participant recruitment.

The code of **"user profile"** are studies that reports difficulty integrating the participants in the session due to their inherent characteristics and personalities. For example, in S1, they report that it "was also an extremely challenging context to work in given the closed nature of these communities". Also, in S22, "due to the children participating's limited communication and social skills, we did not interview children".

The code of **"encouraging participation"** reflects on the trouble of engaging participants with the probe. In S32, they report this difficulty since their session depends on this engagement: "Our approach depends on the users being able to project their future behavior based on a brief acquaintance with the technology probe."

Some studies had difficulty dealing with the context in which their probe was deployed; code **"execution tangibility"** captures this aspect. To illustrate, in S1, they report, "However, this was also an extremely challenging context to work in given the closed nature of these communities, the lack of trust for and fear of outsiders, and the limited amount of time we were able to get with each participant given their fear of being discovered by a family member".

Another challenge that has impacted studies concerns the participants' understanding of the probe's concept and functionality. Two studies openly reported facing this difficulty, representing the code of **"understanding the probe"**. S6 shares that their technique may have biased how participants interacted with the probe, as they taught participants how to use it. In S32, researchers report that "neither child was capable of truly grasping the notion of the audio-based messaging".

Finally, one study reports facing trouble with having a **"broad space of solutions"** related to their probe. S9 states, "We first explored the broad space of solutions [...], their efficacy against an adaptive adversary, and discussed the advantages and disadvantages of each approach", representing a challenge in deciding on a design for the probe.

4.6.7 Probe

The "Probe" category organizes knowledge concerning the type of probe employed in the reviewed studies. It captures variations in how probes were designed and implemented, providing insights into the different technological artifacts that shaped the studies' approaches. The table 4.11 shows this distribution. It is essential to highlight that a study can have multiple probes, with both software—and hardware-based codes.

Table 4.11: Codes from Probe category

Code	**Studies**
hardware-based Probe	S4, S7, S9, S10, S17, S18, S20, S22, S23, S24, S30, S34, S37, S38, S39, S41, S42
software-based Probe	S1, S2, S3, S5, S6, S8, S11, S12, S13, S14, S16, S19, S21, S23, S25, S27, S28, S30, S31, S32, S33, S35, S36, S40
non-technological Probe	S7, S10, S25, S26, S28, S29, S32

The code about **"hardware-based probe"** explicitly showed that the probe consisted of physical devices, such as sensors, wearables, mechanical gloves and watches, voice recorders, cameras, and robots. For example, in S4, a connected shower is a custom-built IoT device, and in S38, they use the Meta Quest Pro headset.

On the other hand, **"software-based probe"** focuses on software solutions used as a probe in the studies. Some examples are mobile applications, web applications, and immersive environment applications.

However, it is essential to highlight that two studies present hardware- and software-based probes. S23 used an application on a wearable device, such as a smartwatch, to conduct its TP. In contrast, S30 utilized a group of different probes, including hardware (voice recorder and cameras) and software (GPS data logger).

The **"non-technological probe"** is a probe that does not present technological components, being, for example, paper-made. S7 used a couple of objects, such as sponges, clothespins, audio gadgets, and circus props, to inspire ideation. S10 also used different artifacts to implement their probe: a list of words, stickers, and a body map. S26, S28, and S29 used a paper prototype to simulate an application.

4.6.8 Pre-TP Session

The "Pre-TP Session" category summarizes activities that researchers conduct before the session, i.e., actions researchers take before the user interacts with the probe itself. It outlines the tasks researchers perform to set the stage for user interaction with the probe, ensuring that the necessary context, instructions, and materials are provided to facilitate a smooth and effective session. Grouping this pre-session activity provides a script of what researchers can do in their studies. Table 4.12 exposes these actions represented by the codes.

Table 4.12: Codes from the Pre-TP Session category

Code	Studies
explanation of the study	S1, S3, S11, S16, S31, S37, S40
familiarization with the probe	S2, S3, S8, S12, S14, S15, S20, S27, S36, S39
informed consent	S1, S3, S20, S37
explanation of the probe	S2, S3, S4, S5, S6, S8, S11, S12, S14, S15, S17, S19, S20, S21, S22, S24, S27, S31, S32, S37, S38, S39, S40
pre-use questionnaire	S3, S17, S36, S38, S42
pre-use interview	S2, S4, S5, S6, S16, S21, S24, S25, S27, S30, S37, S39, S40, S42

The code **"explanation of the study"** summarizes studies that gave participants the research context before the session. S1 and S3 briefly introduce the session, while S11 provides a more detailed explanation: "The initial informal orientation consisted of explaining the session aims and instructions on how to wear the headset and operate the controllers."

Although code names seem similar, **"explanation of the probe"** targets studies that explain the functionality and goals of the probe, not of the study in general. In S11, besides presenting the study, the probe is also instructed. S5, S6, S24, S37, and S38 are studies demonstrating how the probe works. In S39, participants had a training phase before the session, and "participants first had a training phase to gain familiarity with the verbal interaction with the robot".

This quote from S39 also aligns with the concept of 'familiarization with the probe,' in which participants may have contact with the probe, but it does not contribute to the results; rather, it involves understanding the probe before using it. For example, in S12 and S8, participants were allowed to explore the interface for a few minutes.

The code of **"informed consent"** aims to aggregate studies that explicitly state they collected participants' informed consent. In the cases of S1 and S37, oral informed consent was used, S3 employed a digital consent form, and S20 involved a printout.

Finally, the codes **"pre-use questionnaire"** and **"pre-use interview"** focus on studies interested in collecting information about the participants before interacting with the probe. What mainly differs from them is the strategy used. In **"pre-use questionnaire"**, participants filled out a demographic questionnaire (as in S3, S17, S38) or, in some cases, answered open questions about their experience and expectations (S36 and S42). As in the latter, the **"pre-use interview"** aimed to understand the user's background experiences, evident in the listed studies on Table 4.12.

4.6.9 TP-Session Data Collection Strategy

"TP-Session Data Collection Strategy" focuses on planning how data will be gathered during the Technology Probe session. A well-defined data collection strategy is crucial for capturing the most relevant and insightful information from participants. The reviewed studies identified various strategies for gathering data, each tailored to the session's specific goals and the probe's nature. These strategies contribute to understanding user interactions, perceptions, and feedback, forming the basis for further analysis and improvement of probes. Table 4.13 presents the mapped techniques.

Table 4.13: Codes from the Data Collection Strategy category

Code	**Studies**
participant diary logging	S3, S10, S18, S21, S24, S25, S26, S28, S29, S34, S36, S37, S40
researcher fieldnotes	S8, S11, S17, S19, S22, S23, S24, S26, S27, S34, S39, S41
probe log data	S3, S6, S19, S20, S23, S24, S27, S28, S30, S31, S33, S34, S36, S37, S40
participants think-aloud	S2, S8
throughout-study interview	S2, S3, S6, S9, S13, S21, S22, S25, S30, S31, S34, S40, S41
end-user suggestions	S8, S10, S13, S15, S27, S31, S34

Most of the strategies presented consist of strategies to collect qualitative data. **“participant diary logging”** represents a strategy in which participants are invited to register their opinions, experiences, feedback, and perceptions in a diary or a logbook; in S10, participants had a workbook to answer questions and complete activities, for example. S21 had an application: “Each participant was also provided with a ’diary application’ on the phone, inviting them to make note of significant experiences and/or issues as they were to arise during the deployment, as an aide memoire”. Other papers and voicemails were used, and participants were even asked to send their logs via e-mail, as in S24, S34, and S29, respectively.

Researchers’ notes are a crucial source of information in any study, and the Technology Probe is no exception. Studies that explicitly stated they used the researcher’s notes as their strategy to collect data were observed in the code "researcher field notes". In S41, it is vital that “observational methods supported gathering insights from actual practice sessions, capturing cheerleaders’ authentic and natural behavior while avoiding the recall biases that might impact self-reported data”. Not only were written notes considered, but also recordings of sessions and photographs. For example, S23 captured pictures of the sessions, while S26 and S39 used audio and video recordings. Another source of data that does not come directly from the user is the probe log, also known as "probe log data"; it can help in understanding the flow of use of the probe and critical points of functionality. Many studies used technological probes to record and capture usage data. For example, in S20, the videos captured using the probe were analyzed, and in S33, the interactions between users (an adult and a child) were recorded for future analysis.

Considering strategies in which the user has a significant role in providing the data. Two studies reported using the think-aloud protocol to capture the participants’ perceptions during their interaction with the probe. The code "participants think-aloud" puts in evidence S2, where users should express their ideas during the participatory design activity, and S8 to understand which application delivers a better experience.

The code **“throughout-study interview”** aggregates studies that use interviews in the middle of TP sessions. It is valid to highlight that some studies last for days or weeks, during which time interviews are conducted, as seen in the cases of S3, S21, S22, S25, S34, and S40. Some interviews were conducted in person, while others were held over the phone. The goal was to collect feedback, check participants’ perception of the probe, and encourage probe usage. As S21 reports: “Around week eight of the deployment, participants were invited to one of two Interim Group Interviews (of four to five people, 30 minutes in duration) to describe their use experiences and discuss any usability issues they had encountered”.

Lastly, the code regarding ’end-user suggestions’ considers studies that actively collect participants’ suggestions in their research. For example, in S10, the researcher used post-its to capture this, “participants wrote their ideas on post-it notes and then discussed features, applications, and augmentations to the object. After the workshop, each participant was invited to write a brief reflection in the form of a narrative, outlining their positionality, a description highlighting various qualities and affordances of the object (aesthetic, emotional, relational, experiential), and to suggest features, uses, and augmentation to the object. While S13 conducted interviews, “we further conducted an in-depth improvise and interview session with an expert participant, who has extensive professional experience in choreography and dance education, for richer feedback from her perspective”.

4.6.10 TP Session Observation Strategy

Observation is a vital component of the probe as it provides insights into how participants engage with the product and how their feedback is shaped throughout the process. This category aims to group the strategies found in the reviewed articles. The strategies used for observation are designed to capture diverse aspects of user behavior and experience. Table 4.14 shows the observation strategies extracted from the techniques reviewed. It can be observed that some studies employ multiple observation strategies to support their research.

Table 4.14: Codes from the Session Observation Strategy category

Code	Studies
task execution	S2, S3, S8, S10, S12, S14, S16, S17, S26, S28, S29, S30, S34, S36, S39, S42
participatory design workshop	S2, S5, S7, S10, S13, S31, S34, S40
open-ended probe interaction	S1, S4, S5, S6, S9, S11, S12, S13, S15, S16, S17, S18, S19, S20, S24, S27, S28, S30, S32, S33, S35, S36, S38, S39, S40, S41
end-user sketching	S2, S13, S32, S38

The code **“task execution”** explores studies that assign activities for participants to complete during the session. In S16, for example, participants had to perform two specific tasks during the session. Another task example is S36: “we instructed participants to go to the system’s journal view to answer five goal-specification questions. These questions were intended to help participants think critically about their goal and make the goal more specific, actionable, and decomposable”. All studies cited in Table 4.14 show some activity for the user to complete.

The second code **“participatory design workshop”** contains studies that relied on participatory strategies to conduct their observations. In general, co-design workshops were seen to capture participants’ feelings, concerns, and feedback around the probe.

The code of **“open-ended probe interaction”** reflects on studies that let participants use the probe freely and took this opportunity to observe them and collect data. For example, in S27, the instructions regarding using the application were: “use Faced at their discretion during the next three weeks. No compulsory use was required, and users were free to use the application at any time”.

Finally, **“end-user sketching”** are studies that engaged participants in prototyping their ideas for the probe. In S13, the researcher reported “We conducted a low-tech prototyping activity and provided participants with art supplies like paper, sticky notes, colored pens, and highlighters”. We asked them to create concepts of future technologies that could help with improvisational dance-making, inspired by their experience with the MR mirror and the storyboards”. Also, in S38, “these tools included modeling clay, sticky notes, felt pen, perspex, cellophane, paper, whiteboard markers, and scissors. All participants had prior experience with low-fidelity prototyping.”.

4.6.11 Post-TP Session

Just as certain preparatory steps are undertaken before the Technology Probe session, the reviewed studies also revealed practices conducted after the participant had completed their interaction with the probe. The category of ‘Post-TP Session” captures the activities aimed at further exploring participant experiences and gathering additional feedback once the session concluded. Common post-session practices included conducting interviews and administering questionnaires. Table 4.15 shows the distribution of these activities in the studies.

Table 4.15: Codes from the Session Observation Strategy category

Code	Studies
post-use follow-up interview	S1, S2, S3, S4, S5, S6, S8, S9, S10, S11, S12, S14, S15, S16, S17, S18, S19, S20, S21, S23, S24, S25, S26, S27, S29, S32, S37, S38, S40, S42
post-use follow-up questionnaire	S3, S8, S12, S13, S17, S24, S30, S36

Most studies opted to use interviews instead of questionnaires. However, some studies use both strategies. Nonetheless, it is essential to highlight that both codes, **“post-use follow-up interview”** and **“post-use follow-up questionnaire”**, share the same goal; they only differ in the strategy. These codes summarize studies that, after the user interaction with the probe, consult the user regarding their experience with the probe, whether using questionnaires or interviews.

4.7 Discussion

The results obtained through the qualitative analysis enabled us to answer both research questions designed for this study's planning. The rapid review allows researchers to understand Technology Probe's general scenario for technology development. Below, the research questions will be answered, detailing their interpretation of this scenario.

4.7.1 How is Technology Probe being used to evaluate software technologies?

The rapid review results showed that Technology Probe has different uses in software development: promoting co-design, discovering unintended uses, and evaluating the product. The evaluation assesses feasibility, gathers feedback, considers user perception, and identifies key evaluation elements.

When interested in capturing the technology's functionality, studies were motivated to evaluate its feasibility, capturing its manufacturing aspects. Collecting feedback and gathering user opinions aims to assess the technology through the end-user's perspective, focusing on a qualitative evaluation.

To sum up, referring specifically to evaluation software technologies with Technology Probe, the focus is on determining the technical viability of the technology and evaluating the user through their comments and feedback. Nevertheless, the literature review highlighted that the TP is being used to assess and support other aspects of software technology development.

The current research shows the ESE-TechProbe technique, which focuses on using TP for qualitative validation sessions. This aligns with the use of TP as viewed in the literature study. This dissertation aims to provide a technique for qualitatively assessing a software product via TP validation session.

4.7.2 What techniques or practices can support the Technology Probe in software engineering?

The rapid review and process of open coding helped this research identify the techniques that support the use of the Technology Probe in software engineering. The characteristics and common practices of each technique can be captured. Based on an analysis of existing techniques, this section discusses aspects that can be leveraged to support Technology Probe in software engineering.

The categories identified in the process of thematic analysis summarize the techniques observed in the selected articles, presenting the fundamental characteristics of the methods and practices employed when using TP for software engineering. Different facets of the Technology Probe were seen from these categories, some being requirements to apply TP, a couple regarding the organization of the study, others representing expectations researchers might have when using TP, and some foreseen challenges. Figure 4.4 shows these facets related to each category.

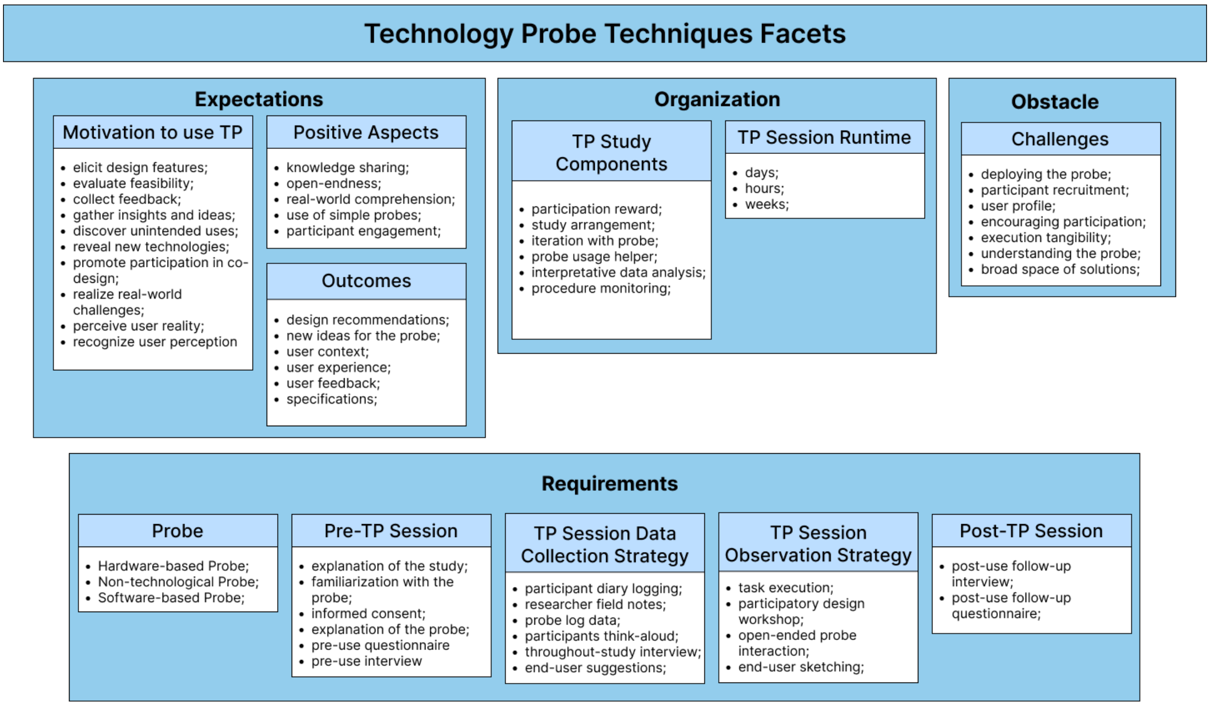


Figure 4.4: Technology Probe Facets

Several techniques and practices can support Technology Probe in software engineering, each contributing to a more structured and insightful technology development. By integrating these approaches, it was possible to outline general facets, characteristics, and practices for techniques in TP to follow (as in Figure 4.4). These facets represent aspects the TP techniques must consider when developing and using them. In this sense, it is possible to assess TP techniques, considering the results obtained and whether the techniques fulfill the required needs, align with the method's expectations, attempt to mitigate the mapped challenges, and take into account the organization's needs. To assess the technique, it is possible to organize the facets and the results perceived from the literature in tables, which helps provide an overview of the techniques.

The facet of **expectations** represents reasons and presumptions researchers may have when choosing the Technology Probe methodology. The motivation to use TP and outcomes expresses desires researchers might have and indicate the use of TP, and positive aspects represent benefits the methods and their techniques may offer. Table 4.16 displays this facet's characteristics and highlights the techniques that must be considered.

Table 4.16: TP Techniques - Expectations

Facets	Characteristic	Checklist	Details
Expectations	Motivation to use TP	What is the motivation behind your TP technique? Choose one or more: ( ) elicit design features ( ) evaluate feasibility ( ) collect feedback ( ) gather insights and ideas ( ) discover unintended uses ( ) reveal new technologies ( ) promote participation in co-design ( ) realize real-world challenges ( ) perceive user reality ( ) recognize user perception	Observations
	Outcomes	What outcomes your technique aims to have? Choose one or more: ( ) design recommendations ( ) new ideas for the probe ( ) user context ( ) user experience ( ) user feedback ( ) specifications	Observations
	Positive Aspects	What are the positive aspects from TP your technique takes advantage? Choose one or more: ( ) knowledge sharing ( ) open-endness ( ) real-world comprehension ( ) use of simple probes ( ) participant engagement	Observations

Organization is about features the researchers need to determine to help build the study, as choosing the desired runtime and deciding the study components, such as participation reward and the session's organization. Table 4.17 enables the assessment of the technique's organization based on the results found in the literature.

Table 4.17: TP Techniques - Organization

Facets	Characteristic	Checklist	Details
Organization	TP Study Components	What are the study components your study aims to have? Choose none, one or more: ( ) participation reward ( ) study organization ( ) iteration with probe ( ) probe usage helper ( ) interpretative data analysis ( ) procedure monitoring	List here other components
	TP Session Runtime	Your TP technique aims in lasting: ( ) days ( ) hours ( ) weeks	Observations

The facet of **obstacle** regards challenges the researcher may encounter when using TP. However, with these possible obstacles mapped, techniques should seek ways to mitigate these troubles. Table 4.18 focuses on the challenges identified in the literature evidence and highlights the importance of having a plan to mitigate these obstacles.

Table 4.18: TP Techniques - Obstacle

Facets	Characteristic	Checklist	Details
Obstacle	Challenges	What are the challenges you foresee your technique facing? Choose none, one or more: ( ) deploying the probe ( ) participant recruitment ( ) user profile ( ) encouraging participation ( ) execution tangibility ( ) understanding the probe ( ) broad space of solutions	How do you intend to mitigate those challenges?

Regarding **requirements**, i.e., elements necessary to compose the technique, without them, conducting the Technology Probe and obtaining valuable results is impossible. To perform a TP session, it is essential to have a piece of technology (the probe), have instruments to understand the user and their pre-conceptions (pre-tp session), define data collection and observation strategies, develop instruments to capture user feedback after the interaction with the probe (post-tp session); and define an estimation for the duration of the session. Table 4.19 summarizes these aspects that researchers need to consider when crafting their technique of Technology Probe.

Table 4.19: TP Techniques - Requirements

Facets	**Characteristic**	**Checklist**	**Details**
Requirements	Probe	What is the piece of technology being submitted for evaluation? Choose one or more: ( ) Hardware-based Probe ( ) Non-technological Probe ( ) Software-based Probe	Observations
	Pre-TP Session	What activities should be done before the participant interacts with the Probe? Choose one or more: ( ) explanation of the study ( ) familiarization with the probe ( ) informed consent ( ) explanation of the probe ( ) pre-use questionnaire ( ) pre-use interview	Observations
	Data Collection Strategy	What will be the chosen strategy the technique will use to collect data? Choose one or more: ( ) participant diary logging ( ) researcher field notes ( ) probe log data ( ) participants think-aloud ( ) throughout-study interview ( ) end-user suggestions	Observations

Facets	Characteristic	Checklist	Details
	Observation Strategy	What will be the chosen strategy the technique will use to observe participants? Choose one or more: ( ) task execution ( ) participatory design workshop ( ) open-ended probe interaction ( ) end-user sketching	Observations
	Post-TP Session	What are the activities to be done after the participant interacts with the Probe? Choose one or more: ( ) post-use follow-up interview ( ) post-use follow-up questionnaire	Observations

These results enabled a critical examination of the ESE-TechProbe, leading to the development of a renewed version for validation sessions focusing on contemporary software systems. The tables presented (fully available in Appendix B) represent a systematic approach to understanding the ESE-TechProbe's strengths and weaknesses and using this analysis to ground the new version of the technique.

4.8 Limitations and Conclusion

The literature study had two major takeaways: (i) understanding the possibilities of using Technology Probe in software development, its utility in evaluating software technologies, and (ii) outlining a guideline researchers can follow to design their TP techniques. Both considered the data extracted from the 42 selected papers, which enabled them to answer the research questions and gain a general understanding of Technology Probe.

The first takeaway highlights TP's potential in software development, including co-creation with end users, discovery of unintended uses, and, as the focus of this research, the evaluation of software technologies. The evaluation mainly focuses on assessing functionality and feasibility and gathering end-user feedback and perceptions of the software product.

As for the second takeaway, the thematic analysis helped comprehend the techniques of Technology Probe used throughout the years in different studies to develop products. A set of categories and codes was obtained, enabling the design of the facets. These facets allow the assessment of TP techniques and can guide their development, as seen in the

Appendix B. Table 4.20 summarizes the results from the thematic analysis, including the facet, categories, and their definitions.

Table 4.20: TP Facets, Categories, and Definitions

Facets	**Category**	**Definition**
Expectations	Motivation to use TP	Aggregates the motivation researchers had to choose the Technology Probe methodology for their work.
Expectations	Positive aspects	Captures the positive aspects of the Technology Probe technique employed, aiming to group benefits and determine what worked well on the TP approach the studies presented.
Expectations	Outcomes	Reports the results the researchers obtained by using Technology Probe.
Organization	TP Study Components	Group characteristics observed in the arrangement of the analyzed studies.
Organization	TP Session Runtime	Duration of the session, i.e., how long the participant interacted with the probe.
Obstacle	Challenge	Difficulties reported when using Technology Probe.
Requirement	Probe	Organize the body of knowledge regarding the study's type of probe.
Requirement	Pre-TP Session	Summarizes activities the techniques conduct before the session, i.e., actions researchers do before the user interacts with the probe.
Requirement	TP-Session Data Collection Strategy	Groups strategies that define how data will be gathered during the Technology Probe session.
Requirement	TP Session Observation Strategy	Methods employed to observe and analyze participant interactions during the Technology Probe session.
Requirement	Post-TP Session	Summarizes activities the techniques conduct after the session, i.e., actions researchers do after the user interacts with the probe.

While this review offers valuable insights into the use of the Technology Probe in software engineering, certain limitations must be acknowledged. It is essential to highlight that the review was conducted by one person (the author of this work) and revised by the supervisor. Although snowballing is a common strategy for rapid review, it was not employed in this work because the number of selected papers was sufficient to collect evidence for the goal of this study. Due to the nature of the rapid review, it was searched only in one library (Scopus); and the search string was simplified, for example, the term "participatory design" was not included since it brought thousands of documents, unabiling the review.

Despite these limitations, the review contributes to the field by organizing the knowledge of Technology Probe throughout the years in technology development and providing evidence for the evolution of the ESE-TechProbe, which will be detailed in the next chapter.

Chapter 5

Evolving the ESE-TechProbe

This chapter presents the result of this research, the improved version of ESE-TechProbe. First, it will discuss how previous results influenced the process, then the proposal itself, and finally, present the technique used to plan an example study.

In Chapter 3, previous versions of the ESE-TechProbe, a Technology Probe technique to support validation sessions, were presented. The timeline of versions of the technique (Figure 3.1) was shown, with the first version in 2018 and the second in 2022. Thus, this chapter aims to present a proposal for the third version of the ESE-TechProbe, based on previous experiences and the results of a literature study regarding the employment of Technology Probe techniques in software development.

The previous experiences provided a set of learned lessons, and the literature study results gave a list of facets and aspects a TP must consider when being crafted. Therefore, the third version of the ESE-TechProbe will take into account these past experiences and the scientific evidence collected.

5.1 Foundations of ESE-TechProbe version 3

5.1.1 Previous Experiences Takeaways

A set of improvement opportunities was identified based on previous experience with the ESE-TechProbe technique. As discussed in Chapter 3, the key points for improvements consist of:

- Instruments to assess participants' emotional reaction:
  - Smiley Faces (Figure 3.2): Currently, the instrument used consists of smiley faces, but past studies have shown that these faces were confusing to participants. Changing how the technique assesses the user reaction and feedback of the probe is an opportunity for improvement.

  - List of adjectives (Table 3.1): In the second version of the ESE-TechProbe, researchers chose not to use the list of adjectives and left it open for participants to write their own adjectives. However, leaving it open left the participants confused. Additionally, when evaluating the first version, participants expressed appreciation for the list of adjectives but criticized its presentation. In this sense, there is an opportunity to incorporate the list of adjectives with a renewed presentation.

- Instrument to support researchers:

  - Note-taking with TP perspectives: The OximeterIoT case made it clear the necessity of an instrument to support researchers' note-taking, considering the three TP perspectives (social, design, and engineering).

  - Experience using ESE-TechProbe: it was recognized as advantageous to have supplementary tools to assist researchers in applying the ESE-TechProbe, enhancing their experience with the technique. These instruments would provide a straightforward guide for using the technique and specify other necessary instruments and materials.

5.1.2 Literature Review Takeaways

The literature study provided a set of facets researchers must consider when tailoring their TP technique, summarized in Table 4.20. A guide to assess TP techniques was possible from these facets and the thematic analysis results, available on Appendix B. The second version of ESE-TechProbe will be submitted to the referenced guide, following the facets to identify opportunities for evolving the technique.

Expectations

Regarding expectation, the second version of the ESE-TechProbe is aligned with the reasons and presumptions observed in the literature study results. The technique shares at least one point with each characteristic, ensuring the checklist is filled in correctly. Table 5.1 presents these results.

Table 5.1: ESE-TechProbe v2 - Expectations

Characteristic	**Checklist**	**Details**
Motivation to use TP	What is the motivation behind your TP technique? Choose one or more: ( ) elicit design features (X) evaluate feasibility ( ) collect feedback (X) gather insights and ideas ( ) discover unintended uses ( ) reveal new technologies ( ) promote participation in co-design ( ) realize real-world challenges (X) perceive user reality ( ) recognize user perception	Observations -
Outcomes	What outcomes your technique aims to have? Choose one or more: ( ) design recommendations ( ) new ideas for the probe ( ) user context (X) user experience (X) user feedback (X) specifications	Observations -
Positive Aspects	What are the positive aspects from TP your technique takes advantage? Choose one or more: ( ) knowledge sharing (X) open-endness (X) real-world comprehension ( ) use of simple probes ( ) participant engagement	Observations -

From the observed motivations of other studies that used the Technology Probe, it is possible to identify shared aspects with the ESE-TechProbe. The present technique evaluates feasibility, gathers insights and ideas, and discovers unintended uses during the validation session by observing participants. Additionally, it aims to capture user reality throughout the study, supported by a pre-designed user journey that helps participants immerse themselves in the usage scenarios.

The outcomes obtained from the second version of the ESE-TechProbe primarily focus on user experience, user feedback, and probe specifications. Aligning with the technique's motivation, the observed results concern user perception and perceived improvements for the product.

The ESE-TechProbe leverages the general positive aspects observed in the Technology Probe method, particularly its open-mindedness. This enables researchers to freely choose the strategy that suits the study best and observe different aspects in a validation session, such as feasibility, user experience, and functionality. Also, the present technique benefits from the characteristic of real-world comprehension.

To sum up, on the facet of expectations, it is evident that the second version of the ESE-TechProbe aligns with the guide. Thus, opportunities for improvement are not seen in this aspect.

Organization

The organizational facet aims to describe the features that researchers need to consider when planning the study. The current version of the ESE-TechProbe has its organizational aspects aligned with the proposed guide obtained through the literature study. Table 5.2 presents the second version of the ESE-TechProbe in organizational terms.

Table 5.2: ESE-TechProbe v2 - Organization

Characteristic	**Checklist**	**Details**
TP Study Components	What are the study components your study aims to have? Choose none, one or more: ( ) participation reward (X) study organization ( ) iteration with probe (X) probe usage helper ( ) interpretative data analysis ( ) procedure monitoring	List here other components: * ESE-TechProbe also uses "user joruney";
TP Session Runtime	Your TP technique aims in lasting: ( ) days (X) hours ( ) weeks	Observations -

As presented in the checklist guide, the ESE-TechProbe also proposes a study organization divided into phases. The first moment gives context to participants, and then the study session is divided into the steps of the user journey. It is essential to highlight the user journey as another component that is not seen in other TP techniques. Another aspect of the ESE-TechProbe is that it helps participants use the probe throughout the session.

The ESE-TechProbe was designed to last for hours, catering to the target audience of contemporary software system users and their participants. This aspect is seen as beneficial for the technique, as it enables valuable insights from users without requiring a study that lasts days or months, leading to a cheaper and easier-to-apply technique.

From the organization's perspective, no opportunity for improvement is seen. The ESE-TechProbe fulfills the characteristics needed to organize and plan its study. Not only is there no improvement in opportunity seen, but the organizational strategies used in the second version of ESE-TechProbe are also beneficial to maintain for the third version.

Obstacle

The perceived challenges of Technology Probe, as identified in the analyzed studies, provided a list of obstacles that researchers should be aware of when using TP techniques. The second version of the ESE-TechProbe is aware of some challenges the technique design may impose and seeks to mitigate them. Table 5.3 illustrates this.

Table 5.3: ESE-TechProbe v2 - Obstacle

Characteristic	**Checklist**	**Details**
Challenges	What are the challenges you foresee your technique facing? Choose none, one or more: (X) deploying the probe (X) participant recruitment (X) user profile ( ) encouraging participation (X) execution tangibility ( ) understanding the probe ( ) broad space of solutions	How do you intend to mitigate those challenges? * Use of "user journey" to mitigate the challenge of deploying the probe and execution tangibility; * Inviting participants by convenience was the strategy to deal with the challenge of recruitment;

The OximeterIoT case, which utilized the second version of ESE-TechProbe, addressed known challenges, including participant recruitment and the tangibility of execution. The first is due to the user profile: healthcare professionals with a tight schedule and limited availability. For that, the recruitment happened conveniently, relying on a network of contacts. The second challenge involves developing a contemporary software system, which poses difficulties in terms of installation within the context of usage and the problem domain of the software system, specifically healthcare. To mitigate this, the researchers considered using user journeys to immerse participants in the usage context and simulate the moment of use.

Although the ESE-TechProbe may encounter these challenges, it already has mechanisms in place to address them. In the OximeterIoT case, these mechanisms effectively mitigated the challenges and enabled the study to proceed accordingly. Thus, regarding the facet of obstacles, there is no need for improvement in the third version.

Requirements

The requirement facet presents elements that must be present in the crafted technique. As seen in the second version of the ESE-TechProbe, several aspects fulfill some requirements. However, while the technique incorporates some of these components, opportunities remain to enhance the overall experience for researchers. Notably, the requirement facet has a significant role in guiding potential improvements. Table 5.4 illustrates this observation.

Table 5.4: ESE-TechProbe v2 - Requirements

Characteristic	**Checklist**	**Details**
Probe	What is the piece of technology being submitted for evaluation? Choose one or more: (X) Hardware-based Probe ( ) Non-technological Probe (X) Software-based Probe	Observations * Since the probes consist of an IoT software system, it has both software and hardware;
Pre-TP Session	What are the activities to be done before the participant interacts with the Probe? Choose one or more: (X) explanation of the study (X) familiarization with the probe ( ) informed consent ( ) explanation of the probe ( ) pre-use questionnaire ( ) pre-use interview	Observations * It has activities defined in the pre-session, but some possibilities are seen to refine the study;

Characteristic	Checklist	Details
Data Collection Strategy	What will be the chosen strategy the technique will use to collect data? Choose one or more: ( ) participant diary logging (X) researcher field notes ( ) probe log data (X) participants think-aloud ( ) throughout-study interview (X) end-user suggestions	Observations * The technique fulfills the requirement of having the data collection strategy defined, but the instruments used in these strategies presents opportunities for improvement;
Observation Strategy	What will be the chosen strategy the technique will use to observe participants? Choose one or more: () task execution ( ) participatory design workshop (X) open-ended probe interaction ( ) end-user sketching	Observations -
Post-TP Session	What are the activities to be done after the participant interacts with the Probe? Choose one or more: ( ) post-use follow-up interview ( ) post-use follow-up questionnaire	Observations -

An artifact representing a technological solution, the probe, is essential for the Technology Probe. It can be represented by software and/or hardware components or even prototypes made with paper or design software. The ESE-TechProbe already started from this premise when the study was being planned. Considering the OximeterIoT, the probe consisted of various hardware components, including sensors and software systems, as well as web applications. In this aspect, the ESE-TechProbe fulfills the requirement and doesn't need any improvement.

Regarding the characteristics of a pre-TP session, the current ESE-TechProbe presents a ritual before the participants interact with the probe. In the reported experience, this ritual was explained in the study, accompanied by slides to support the presentation. Participants were also given a brief opportunity to become familiar with the probe.

At this point in the technique, the possibility of incorporating questionnaires to capture demographic data about the users and also considering instruments to register participant perception before fully understanding the probe is evident, as this would stimulate creativity to assist with the co-creation aspect of the TP. Additionally, it is essential to consider the necessity of participants completing an informed consent questionnaire for ethical reasons.

The second version of ESE-TechProbe employs diverse strategies to capture the necessary data, including researcher fieldnotes, participants' think-alouds, and end-user suggestions. Researchers write free notes on the sessions, capturing the suggestions and important points from the think-aloud process. Additionally, the current technique utilizes an instrument to record end-user suggestions throughout the session, as illustrated in Figure 3.4.

There were two opportunities to evolve the instruments used in this part of the technique. First, as reported by NASCIMENTO *et al.* (2024) in previous experiences, researchers need an appropriate instrument to take notes. Secondly, change how the questionnaire captures users' perceptions and feelings, as it was reported that the faces (Figure 3.2) may be confusing when answering it.

For this characteristic, the second version of ESE-TechProbe lets participants openly interact with the technology following the script of the user journey. This is seen as a benefit of the technique, as it does not restrain the participant and allows the session to flow according to the participant's curiosity about the probe. Researchers must design and follow the user journey to simulate real-world usage scenarios, guide their observations, and ensure that participants are aligned with the context.

Finally, the characteristic that has the most opportunity to impact the third version of the ESE-TechProbe is the Post-TP session. The current technique lacks a defined instrument to capture user experience, perception, and opinion after interacting with the probe. The reviewed studies emphasize the importance of having a post-use follow-up with interviews or questionnaires. This analysis led to an opportunity to incorporate this into the technique, as it's a must-have from a literature perspective.

Therefore, the second version of the ESE-TechProbe presents opportunities for improvement within the requirements facet. Urgently, the technique does not fulfill this requirement in the Post-TP session. Additionally, there are opportunities to enhance instruments during the Pre-TP session, including the collection of informed consent and demographic questions, as well as in the instruments used to capture the user's perception and opinion regarding the probe.

5.1.3 Key Takeways

The sections above detailed the opportunities for improvement ESE-TechProbe may have in its newer version. Previous experiences have shown options for the instruments used to capture user perception and support researchers' experiences applying the technique. The literature study also primarily revealed opportunities related to instruments. The third version of ESE-TechProbe presents enhanced ways to capture users' perceptions, emotions, and feedback, promoting user creativity. Below is a list that concentrates on the opportunities for improvement:

- Pre-TP Session Instruments;
- Instruments to assess users' emotional reactions to the probe;
- Activities to provoke user creativity to suggest new ideas and unintended uses;
- Instruments to support researchers' note-taking;
- Instruments to support researchers in using the technique, and;
- Post-TP Session activities to register users' final perception.

5.2 ESE-TechProbe: version 3

As seen above, the evolution of the ESE-TechProbe was based on scientific evidence and previous experience with the technique. Some aspects were maintained, while others were added or enhanced. This section aims to detail and explore this new version.

The third version aims to maintain the essence of ESE-TechProbe, as seen in previous versions: to represent a technique of Technology Probe that supports validation sessions within the validated learning cycle. Still focuses on understanding user experience, product acceptability, field testing, and user ideation. Additionally, this version aims to aid the development of contemporary software systems, since it's filled with uncertainty and difficulty in understanding user needs and eliciting their requirements and specifications. In general, the goal as the focus of the version was maintained, also some practices were kept (as the user journey and think-aloud protocol); however, instruments were generally changed from the second version to the third.

The section above summarizes the perceived opportunities for improvement in this third version, which primarily consists of three points: pre-TP session, data collection, and post-TP session. Table 5.5 presents the proposal for each point, putting versions side by side.

Table 5.5: Improvements from Version 2 to Version 3

Point	**Practice**	**Version 2**	**Version 3**
Pre-TP Session	Activities	* Explanation of the Study * Familiarization with the Probe	* Explanation of the Study * Familiarization with the Probe * Informed Consent * Pre-use questionnaire
	Instruments and/or Materials	* Explanation material	* Explanation Material * Informed consent form * Demographic Questionnaire * Questionnaire to capture pre-use perception and provoke creativity
Collect user perception during the session	Activities	* Researchers' Note-taking ad-hoc * Think-aloud protocol * User Journey questionnaires	* Researchers' Note-taking following a designed instrument * Think-aloud protocol * Refined User Journey questionnaires
	Instruments and/or Materials	* User Journey questionnaires (Figure 3.4)	* Refined User Journey questionnaires using other instruments to register user reaction (Figure 5.1 and Table 5.6)
Post-TP Session	Activities	None	* Post-use questionnaire
	Instruments and/or Materials	None	* Questionnaire to capture post-use perception, feedback, and suggestions for the probe

Highlighting the instruments that will be used to assess the user perception instead of the Smiley Faces. Since participants in previous experiences reported confusion in registering their opinions, a change was thought of. This way, participants will use a visual analogue scale to rate their experience with the probe, as presented in Figure 5.1. The usage of the VAS scale aims to simplify the process of assessing user satisfaction, using numbers. In addition, with the correct scale, it is useful for researchers, since the VAS enables to use of statistics to analyze the user answers.

Alongside the scale, participants will be asked to choose from the list of adjectives that describe the probe for them, selecting either positive or negative adjectives, as listed in Table 5.6. This list of adjectives was already used in the ESE-TechProbe version 1 and it was based on the Microsoft Reaction Cards (BENEDEK and MINER, 2002).

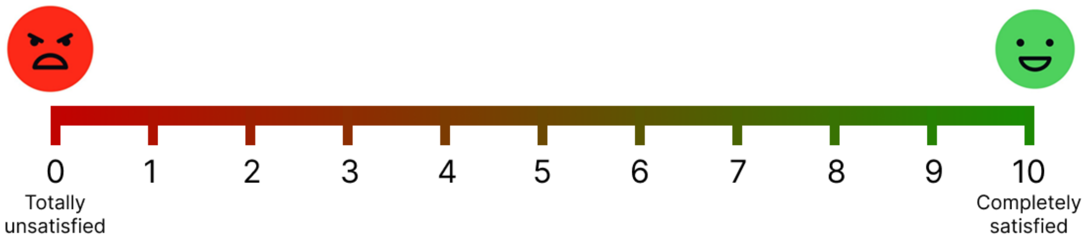


Figure 5.1: Visual Analogue Scale to assess user experience

Table 5.6: Adjectives to support self-reporting emotional reactions

Positive	**Negative**
Accessible	Annoying
Consistent	Boring
Desirable	Confusing
Empowering	Dull
Fast	Frustrating
Helpful	Hard to use
Intuitive	Ineffective
Motivating	Old
Novel	Poor quality
Relevant	Rigid
Stimulating	Stressful
Valuable	Unattractive

Given these aspects that will improve the technique, it is valid to detail the course of action of the third version. The diagram 5.2 shows the activities the researchers must go through to plan and conduct a study using the ESE-TechProbe v3.

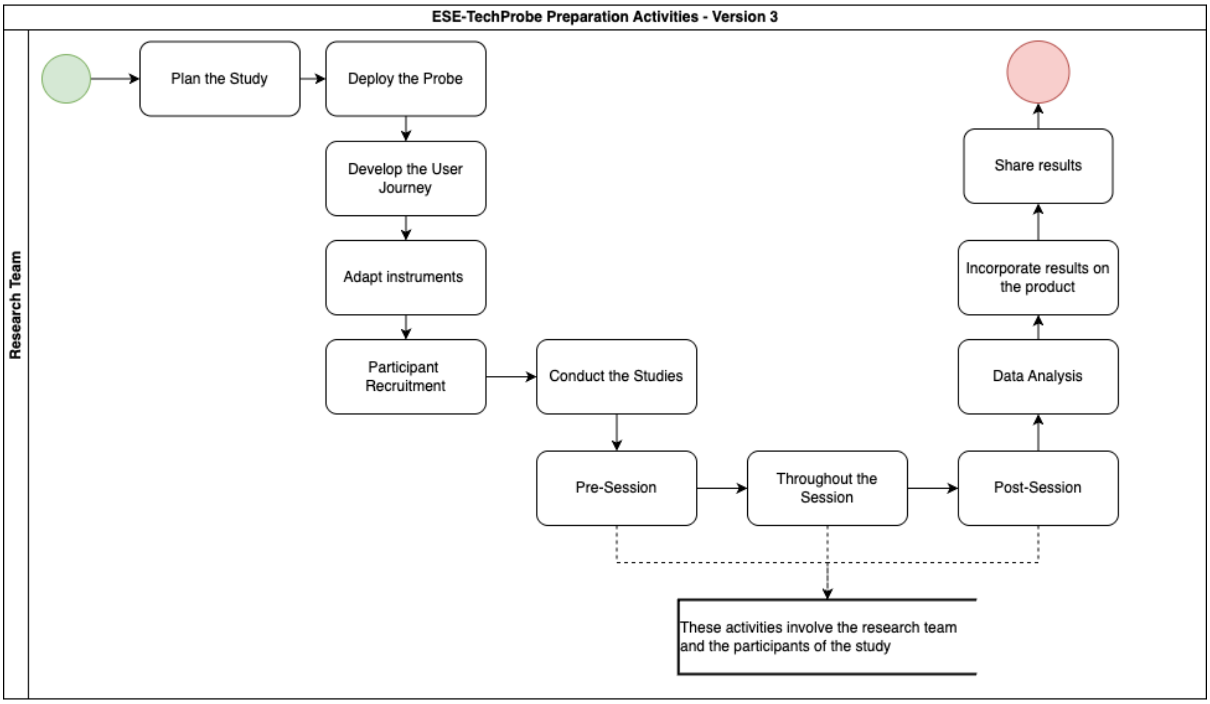


Figure 5.2: Flow of activities of ESE-TechProbe version 3

Figure 5.2 presents the steps researchers must follow to apply the technique, describing the pre-study, during-study, and post-study moments. Pre-study comprehension includes planning and preparation activities. During the study, it represents activities regarding the sessions, including the pre-session, throughout the session, and post-session. Finally, post-study activities are the steps researchers must take to conclude their study and present the final results.

While Figure 5.2 highlights the process of planning a study using the technique, Diagram 5.3 details the organization of an ongoing session, outlining the steps involved in pre-session, during the session, and post-session. The diagram follows a similar structure to the flow of activities from the first version (Figure 3.3) and the second version (Figure 3.5). However, it follows the user journeys, presenting more questionnaires to be assessed (as in the second version), highlights the use of the think-aloud protocol throughout the session, and points out actions of the researchers.

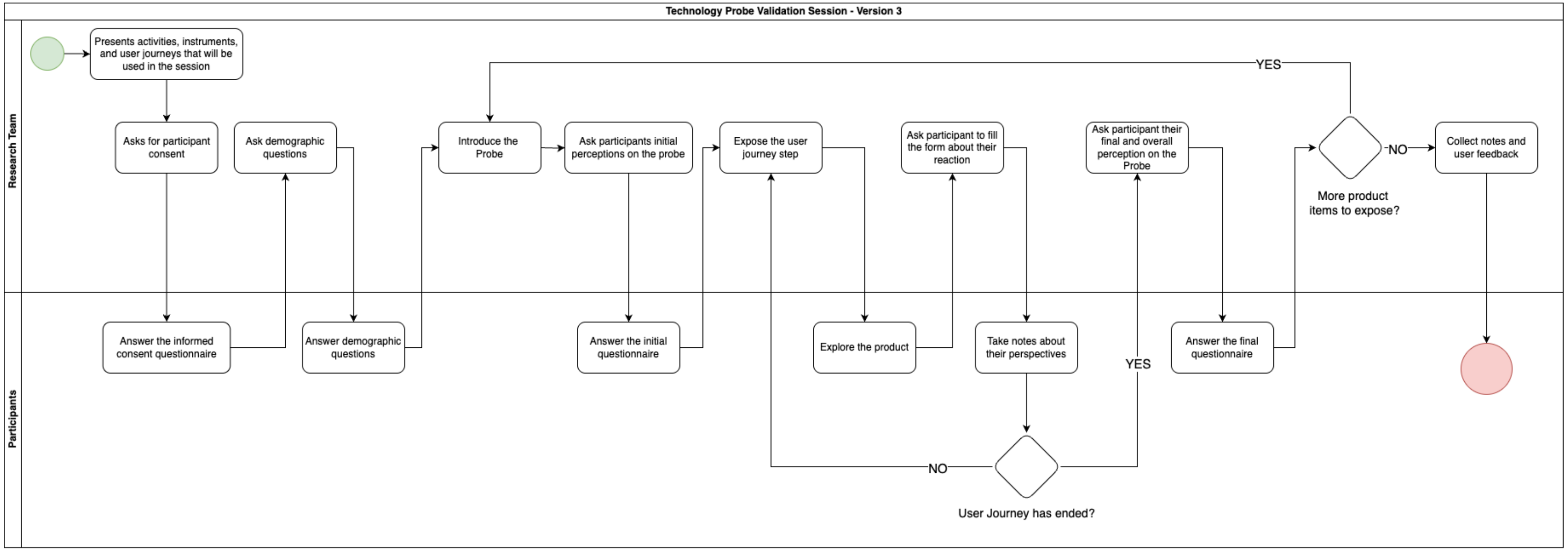


Figure 5.3: Flow of activities of ESE-TechProbe version 3 Validation Session

The subsections below detail each step in applying the technique: pre-study, during the study (pre-session, throughout the session, and post-session), and post-study. They provide the context, expected activities, and associated instruments for each step.

5.2.1 Pre-Study

Planning, organizing, and preparing the materials and instruments are vital to any study. The Pre-study phase aims to group these tasks to guarantee that the survey goes according to plan. In a study based on Technology Probe, a probe is necessary, and specifically, following the ESE-TechProbe, other materials are needed. The key activities of this moment are:

- Planning the study;
- Deploying the probe;
- Developing the User Journey;
- Adapting the instruments;

Planning the study requires a significant amount of effort on the part of the research team, including foreseeing potential cases, defining the sample of participants, recruiting participants, writing the study protocol, determining the data to be captured, and performing other tasks. To help researchers apply the ESE-TechProbe, a document was created to provide the basic steps they need to follow in planning their experiments based on the ESE-TechProbe technique. It aims to assist in completing questionnaire templates and the researcher's reasoning to determine if the Technology Probe is the correct methodology for the research. This instrument is available in two formats: as a PDF document file and on the website.

PDF Document This document explains how to apply the technique step by step, detailing the usage of each questionnaire and providing an explanation and guide on executing the session. Figure 5.4 shows a preview of the document, and the Appendix D presents the document fully.

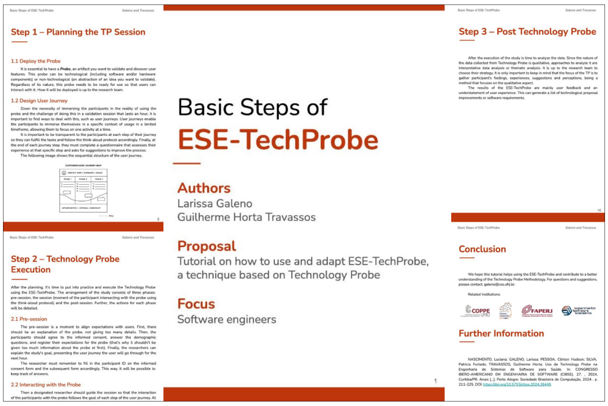


Figure 5.4: Preview of the Basic Steps Document

Website: The website has the same content as the PDF document, but with an additional section on fundamental concepts. Additionally, you can download all documents (in PDF or Microsoft Word format for editing) directly from the site (`https://ese-techprobe.vercel.app/index.html`). Figure 5.5 presents the site's homepage.

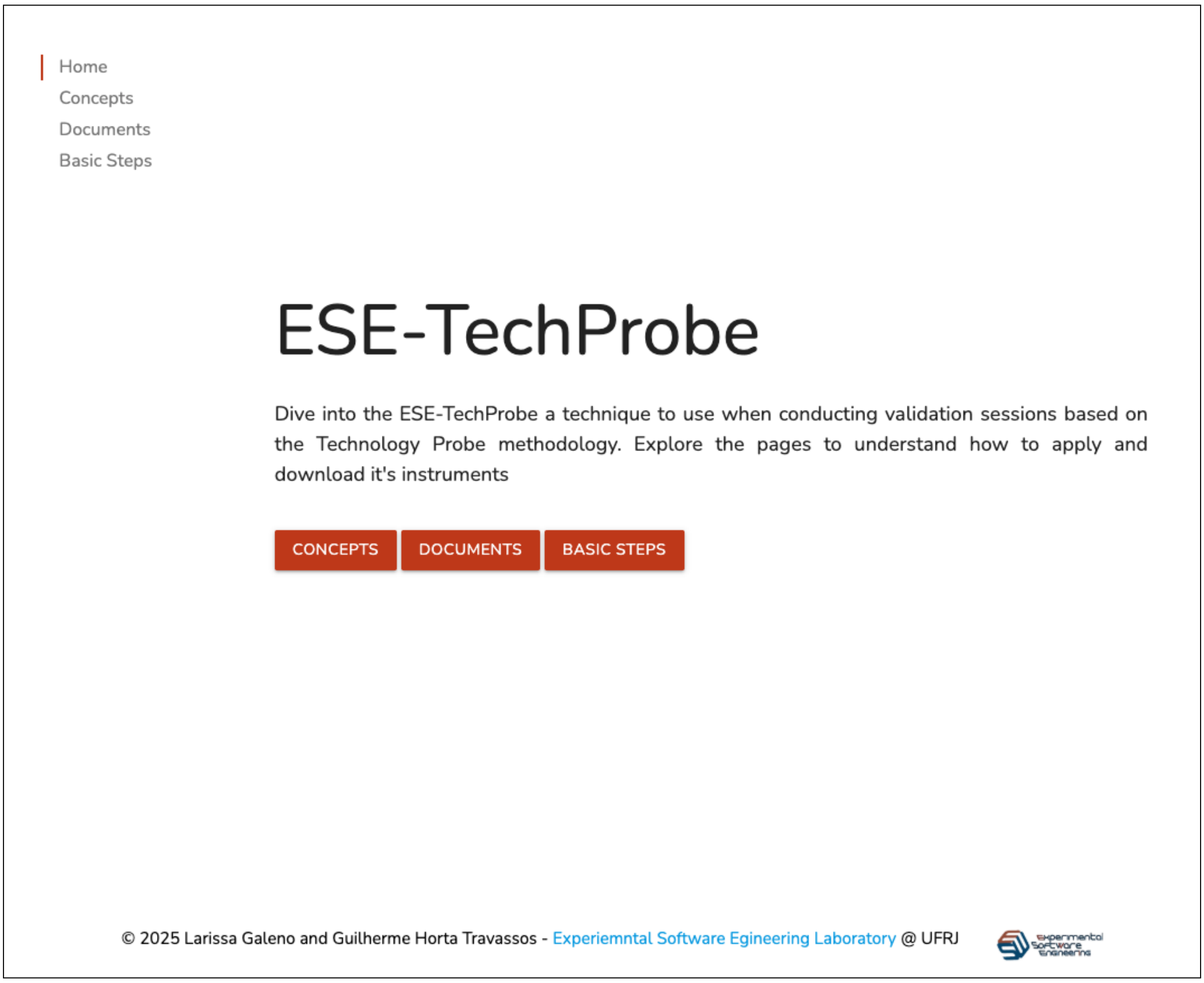


Figure 5.5: Preview of the Website

Deploying the probe will depend on each study's making its technological artifact available for the users to interact with during the session. Each technological product may vary in its need for deployment, and it's up to the researcher to deploy it accordingly to meet the study's needs.

Designing the user journey for the third version of the ESE-TechProbe is essential. The steps of the Journey will guide the user's interaction with the probe during the session, helping them immerse themselves in the scenarios and context of the product's usage. It is up to the researchers to design their User Journey according to their needs.

Adapting the instruments is crucial before starting the study. Hints on how to do this can be found in the basic steps document (Appendix D). With these adapted instruments, the researcher will have a set of questionnaires ready to assess users' perception, emotional reaction, feedback, and suggestions.

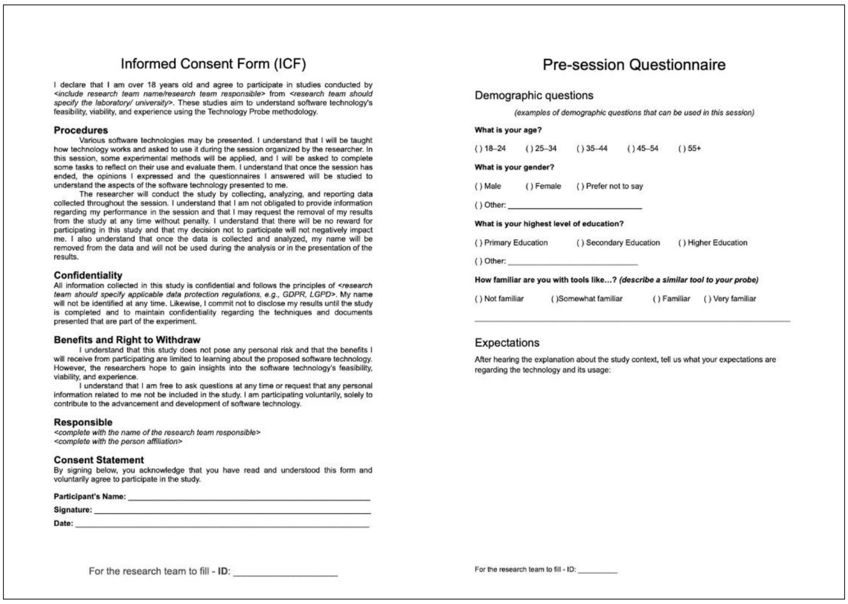
5.2.2 During the Study

The study is then divided into three parts: pre-session, before the participant interacts with the probe; throughout the session, while the participant interacts with the probe; and post-session, after the participant interacts with the probe. In the third version of the ESE-TechProbe, each part features a set of distinct activities and instruments that must be utilized.

Pre-Session

The pre-session serves as an opportunity to align expectations with users. It begins with briefly explaining the study and the probe, ensuring that excessive details are not provided upfront. Next, participants must review and agree to the informed consent, complete demographic questions, and record their expectations for the probe — hence the importance of limiting initial information. At this moment, researchers should clarify the study's objective and introduce the user journey participants will experience over the next hour. The template for the Informed Consent Questionnaire is available in the Appendix C and is previewed in Figure 5.6.

The questionnaires at this step gather participant consent, demographic information (if deemed relevant by the research team), and, most importantly, their expectations regarding the probe. This questionnaire should be administered after a brief introduction to the probe, ensuring that participants have a basic understanding to inform their responses. Capturing their expectations encourages creativity, providing valuable insights that researchers can use to refine and enhance the technology, being aligned with the social perspective of the Technology Probe method. Figure 5.6 also previews this instrument, and is fully available in Appendix F



Informed Consent Form (ICF)

I declare that I am over 18 years old and agree to participate in studies conducted by *<include research team name/research team responsible>* from *<research team should specify the laboratory/ university>*. These studies aim to understand software technology's feasibility, viability, and experience using the Technology Probe methodology.

Procedures

Various software technologies may be presented. I understand that I will be taught how technology works and asked to use it during the session organized by the researcher. In this session, some experimental methods will be applied, and I will be asked to complete some tasks to reflect on their use and evaluate them. I understand that once the session has ended, the opinions I expressed and the questionnaires I answered will be studied to understand the aspects of the software technology presented to me.

The researcher will conduct the study by collecting, analyzing, and reporting data collected throughout the session. I understand that I am not obligated to provide information regarding my performance in the session and that I may request the removal of my results from the study at any time without penalty. I understand that there will be no reward for participating in this study and that my decision not to participate will not negatively impact me. I also understand that once the data is collected and analyzed, my name will be removed from the data and will not be used during the analysis or in the presentation of the results.

Confidentiality

All information collected in this study is confidential and follows the principles of *<research team should specify applicable data protection regulations, e.g., GDPR, LGPD>*. My name will not be identified at any time. Likewise, I commit not to disclose my results until the study is completed and to maintain confidentiality regarding the techniques and documents presented that are part of the experiment.

Benefits and Right to Withdraw

I understand that this study does not pose any personal risk and that the benefits I will receive from participating are limited to learning about the proposed software technology. However, the researchers hope to gain insights into the software technology's feasibility, viability, and experience.

I understand that I am free to ask questions at any time or request that any personal information related to me not be included in the study. I am participating voluntarily, solely to contribute to the advancement and development of software technology.

Responsible

<complete with the name of the research team responsible>
<complete with the person affiliation>

Consent Statement

By signing below, you acknowledge that you have read and understood this form and voluntarily agree to participate in the study.

Participant's Name: ______________________

Signature: ______________________

Date: ______________________

For the research team to fill - **ID:** ____________

Pre-session Questionnaire

Demographic questions

(examples of demographic questions that can be used in this session)

What is your age?

( ) 18–24 ( ) 25–34 ( ) 35–44 ( ) 45–54 ( ) 55+

What is your gender?

( ) Male ( ) Female ( ) Prefer not to say

( ) Other: ______________

What is your highest level of education?

( ) Primary Education ( ) Secondary Education ( ) Higher Education

( ) Other: ______________

How familiar are you with tools like...? *(describe a similar tool to your probe)*

( ) Not familiar ( )Somewhat familiar ( ) Familiar ( ) Very familiar

Expectations

After hearing the explanation about the study context, tell us what your expectations are regarding the technology and its usage:

For the research team to fill - ID: ________

Figure 5.6: Preview of the Informed Consent and the Initial Questionnaire

Researchers must also ensure that the participant ID is correctly recorded on both the informed consent form and subsequent forms to facilitate response tracking.

Throughout the Session

After completing both initial questionnaires, the participant should start interacting with the probe. A designated researcher will guide the session so that the participant's interaction with the probe smoothly follows the user's journey. The research team needs to observe the participants' actions and carefully listen to their opinions while they comply with the think-aloud.

At the end of each step of the user journey, participants must answer a questionnaire regarding their perceptions of that step. Figure 5.7 shows it (available in Appendix G). This instrument aims to assess their experience in a particular step (using the visual analog scale from Figure 5.1) and register any reflections they may have regarding possible improvements for the probe. It stimulates their creativity and co-creation, a fundamental point for the Technology Probe's social and design aspects.

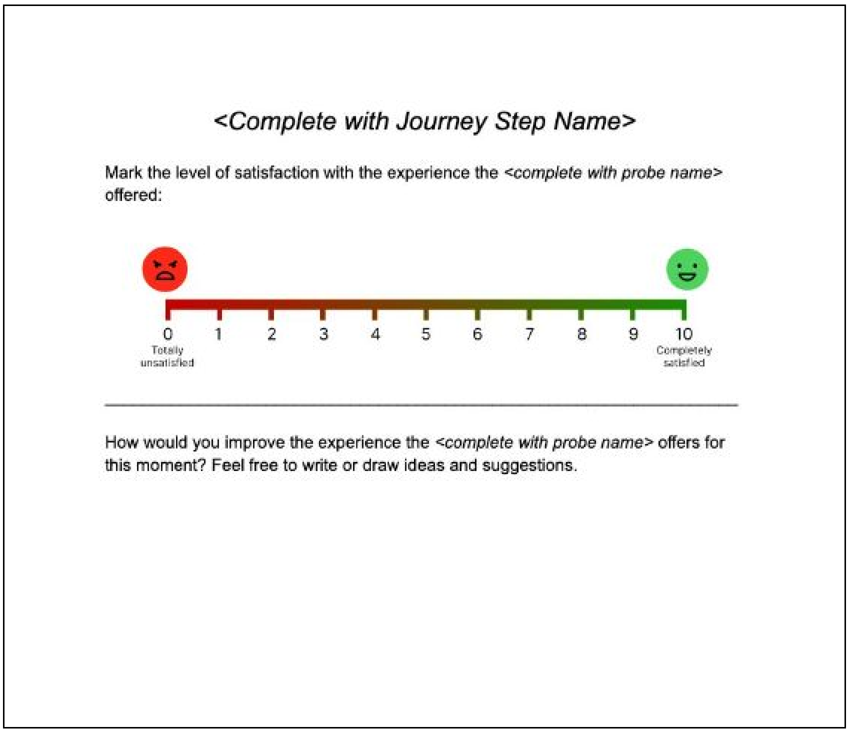
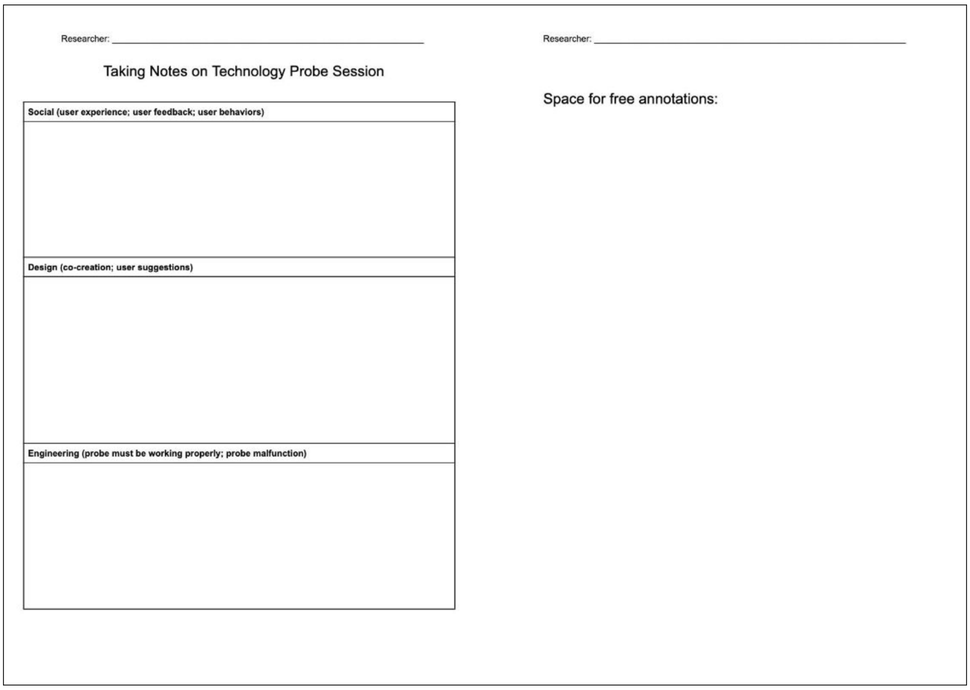


Figure 5.7: Preview of the Questionnaire to assess user perception at the end of Journey Step

Besides the participants' activities, at this point in the study, the researcher must also take notes about users' feedback and perceptions during their interaction with the probe using the think-aloud protocol. To assist researchers in taking notes, an instrument is being proposed to support their fieldnotes aligned with the three Technology Probe perspectives (design, social, and engineering). Figure 5.8 shows the document's header and is fully available on Appendix E.


Researcher: ______________________________

Taking Notes on Technology Probe Session

Social (user experience; user feedback; user behaviors)
Design (co-creation; user suggestions)
Engineering (probe must be working properly; probe malfunction)

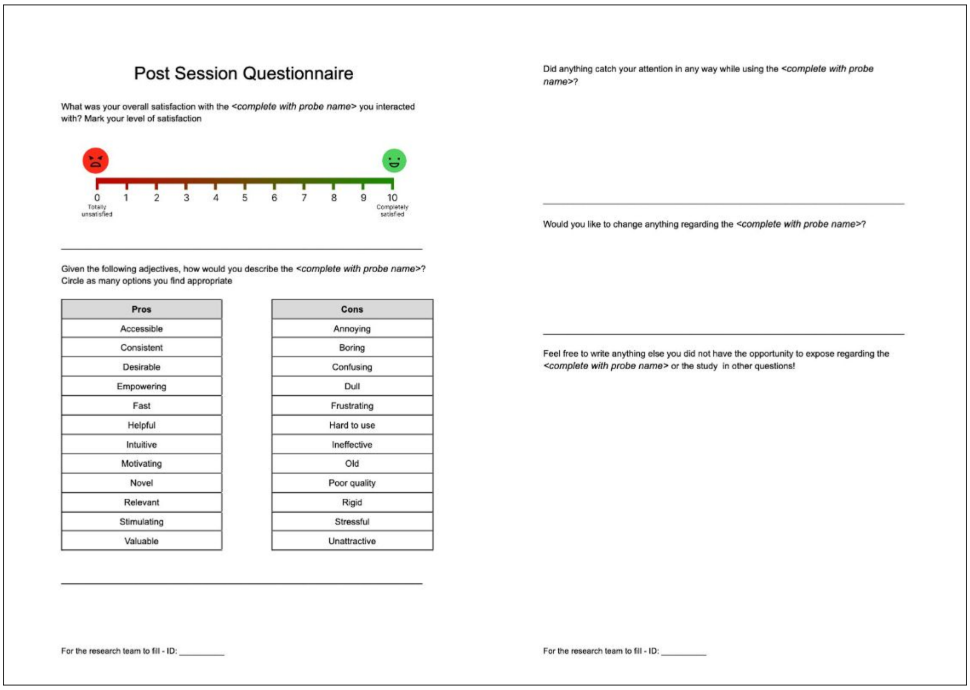
Researcher: ______________________________

Space for free annotations:

Figure 5.8: Preview of the instrument to support researchers' fieldnotes

Post-Session

After completing the user journey, participants will reach the post-session phase. They will be asked to complete a questionnaire to share their opinions on the probe. First, they will rate their overall experience using the visual analogue scale (Figure 5.1). Next, they will evaluate the technological proposal by selecting from a predefined set of adjectives based on BENEDEK and MINER (2002), represented in Table 5.6. After this, open-ended questions will be provided to gather positive and constructive feedback. Lastly, an optional open field will allow participants to share final thoughts or considerations. This final instrument represents the perspective of Design, as it seeks suggestions and co-creation, and also the Social perspective, which captures final user feedback and perception. This questionnaire is previewed in Figure 5.9 and is available in Appendix H.



Post Session Questionnaire

What was your overall satisfaction with the *<complete with probe name>* you interacted with? Mark your level of satisfaction

0 Totally unsatisfied, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 Completely satisfied

Given the following adjectives, how would you describe the *<complete with probe name>*? Circle as many options you find appropriate

Pros
Accessible
Consistent
Desirable
Empowering
Fast
Helpful
Intuitive
Motivating
Novel
Relevant
Stimulating
Valuable

Cons
Annoying
Boring
Confusing
Dull
Frustrating
Hard to use
Ineffective
Old
Poor quality
Rigid
Stressful
Unattractive

For the research team to fill - ID: ________

Did anything catch your attention in any way while using the *<complete with probe name>*?

Would you like to change anything regarding the *<complete with probe name>*?

Feel free to write anything else you did not have the opportunity to expose regarding the *<complete with probe name>* or the study in other questions!

For the research team to fill - ID: ________

Figure 5.9: Preview of the instrument to support researchers' fieldnotes

5.2.3 Post Study

Finally, with all the questionnaires filled out and data collected from the researchers, it's time to conduct the data analysis. Given the qualitative nature of the data collected through Technology Probe, appropriate analytical approaches include interpretative data analysis or thematic analysis. The selection of a specific strategy is at the discretion of the research team; however, it is essential to acknowledge that TP primarily aims to capture participants' emotions, experiences, suggestions, and perceptions, emphasizing its qualitative focus.

The outcomes of the ESE-TechProbe predominantly consist of user feedback and insights into user experience. These findings can inform the refinement of the technological proposal, contributing to a list of potential improvements or software requirements.

5.3 ESE-TechProbe in Practice – OximeterIoT

As discussed in Chapter 3.2.1, the second version of ESE-TechProbe was previously used in a validation session with the probe OximeterIoT. To illustrate the proposal for the third version of ESE-TechProbe, the following subsections provide an example of the renewed version in a validation session of OximeterIoT. The subsections below will be aligned with the steps described above: pre-study, during the study (pre-session, throughout the session, post-session), and post-study.

5.3.1 Pre-Study

At this moment, planning and organization activities are needed. The probe, in this case the OximiterIoT illustrated in Figure 3.6, must be deployed. Having an operating device is enough for the deployment of this study.

It is then necessary to design the user journey. For this example, the same user journey will be used as previously reported in the TP sessions. Figure 5.10 shows this journey, which will be extremely important in designing the other instruments.

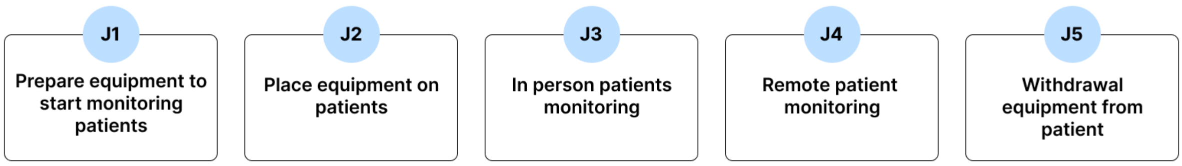


Figure 5.10: User Journey Example (Translated from NASCIMENTO *et al.* (2024)

At this stage, it is also necessary to prepare the explanation material. Following the ESE-TechProbe technique, the explanation material should focus on aligning expectations with the participant, briefly explaining the study and the probe. Figure 5.11 shows a preview of the prepared slideshows, which can be fully read in Appendix I.

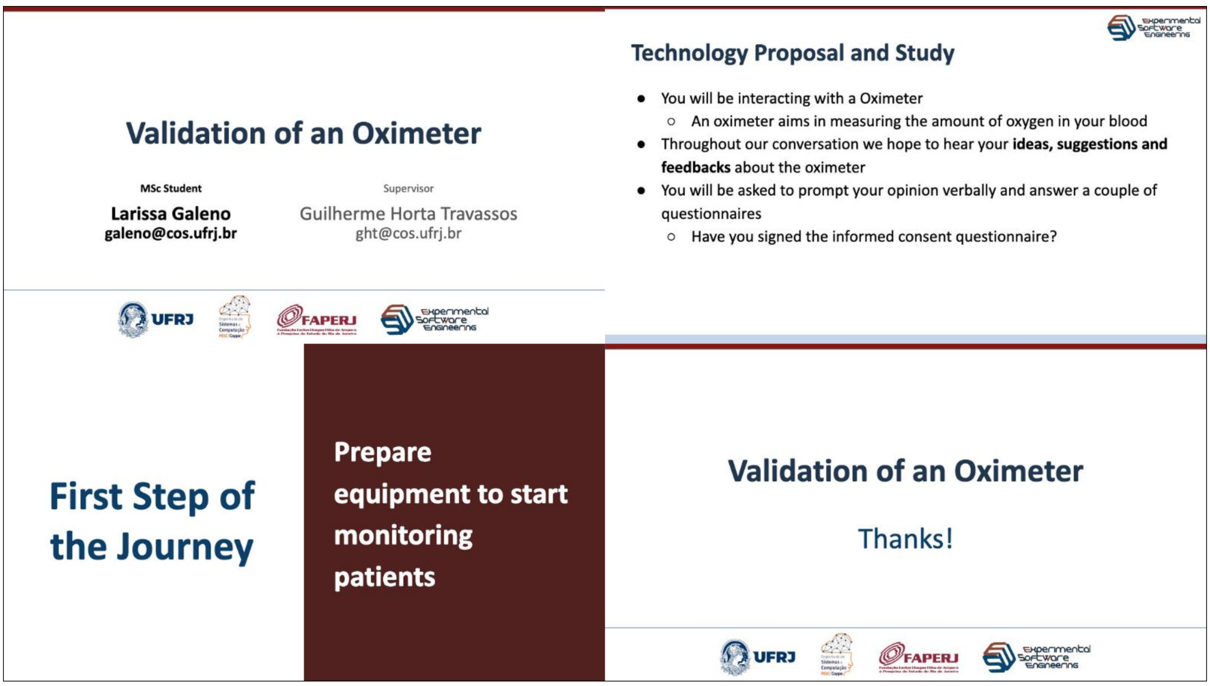


Figure 5.11: Preview of an example of Explanation Material

Finally, the questionnaire templates must be adjusted to the study's needs. Adjustments vary between instruments; they can include the probe name, title of journey steps, or elaborating demographic questions. Below are examples of the instruments edited.

5.4 During the Study

In this phase, the researchers are expected to use different styles of adjusted questionnaires in each step (pre, throughout, or post-session). The subsections will present how these instruments would be adapted for the OximiterIoT case.

Pre-session

The pre-session has two moments that require an adapted instrument: informed consent and the initial questionnaire, which assesses demographic questions and first impressions. The informed consent form is a requirement to conduct this study. Figure 5.12 shows the adapted informed consent.

Informed Consent Form (ICF)

I declare that I am over 18 years old and agree to participate in studies conducted by Larissa Galeno from the Experimental Software Engineering Laboratory - UFRJ. These studies aim to understand software technology's feasibility, viability, and experience using the Technology Probe methodology.

Procedures

Various software technologies may be presented. I understand that I will be taught how technology works and asked to use it during the session organized by the researcher. In this session, some experimental methods will be applied, and I will be asked to complete some tasks to reflect on their use and evaluate them. I understand that once the session has ended, the opinions I expressed and the questionnaires I answered will be studied to understand the aspects of the software technology presented to me.

The researcher will conduct the study by collecting, analyzing, and reporting data collected throughout the session. I understand that I am not obligated to provide information regarding my performance in the session and that I may request the removal of my results from the study at any time without penalty. I understand that there will be no reward for participating in this study and that my decision not to participate will not negatively impact me. I also understand that once the data is collected and analyzed, my name will be removed from the data and will not be used during the analysis or in the presentation of the results.

Confidentiality

All information collected in this study is confidential and follows the principles of LGPD. My name will not be identified at any time. Likewise, I commit not to disclose my results until the study is completed and to maintain confidentiality regarding the techniques and documents presented that are part of the experiment.

Benefits and Right to Withdraw

I understand that this study does not pose any personal risk and that the benefits I will receive from participating are limited to learning about the proposed software technology. However, the researchers hope to gain insights into the software technology's feasibility, viability, and experience.

I understand that I am free to ask questions at any time or request that any personal information related to me not be included in the study. I am participating voluntarily, solely to contribute to the advancement and development of software technology.

Responsible

Larissa Galeno
MSc Student at COPPE/UFRJ
Guilherme Horta Travassos
Professor at COPPE/UFRJ

Consent Statement

By signing below, you acknowledge that you have read and understood this form and voluntarily agree to participate in the study.

Participant's Name: ____________________

Signature: ____________________

Date: ____________________

For the research team to fill - **ID**: ____________

Figure 5.12: Informed Consent

While Figure 5.13 shows the adapted pre-session questionnaire, with demographic questions and asks about participants' expectations of the probe. The chosen demographic questions were essentially due to the user profile and the context in which they would interact with the probe; it aimed to know participants better. After these questions, they are asked to describe their thoughts on the oximeter based on their introduction.

Pre-session Questionnaire

Demographic questions

What is your current occupation in the healthcare field? (Select all that apply)

( ) Physician ( ) Nurse ( ) Pharmacist ( ) Medical Assistant ( ) Technician

( ) Researcher/Scientist ( ) Medical Student/Resident

( ) Other: ______________________________

Where do you primarily work? (Select one)

( ) Private Hospital ( ) Public Hospital ( ) Clinic

( ) University/Research Institue ( ) Home Care

( ) Other: ______________________________

What is your typical work schedule? (Select one)

( ) Day Shifts only ( ) Night Shifts only ( ) Rotating shifts ( ) Flexible schedule

( ) Other: ______________________________

How many years have you been working in healthcare? (Select one)

( ) Less than 1 year ( ) 1-5 years ( ) 6-10 years ( ) 11-20 years ( ) More than 20 years

( ) Other: ______________________________

How familiar are you with tools like an Oximeter?

( ) Not familiar ( )Somewhat familiar ( ) Familiar ( ) Very familiar

Expectations

After hearing the explanation about the study context, tell us what your expectations are regarding the technology and its usage:

For the research team to fill - ID: __________

Figure 5.13: Pre-session Questionnaire

Throughout-session questionnaires

To collect participants' opinions while interacting with the probe, they must answer questionnaires every time they finish a step of the journey. Since the designed user journey has five steps, there are five questionnaires accordingly. Figure 5.14 previews this questionnaire, and they are available in the Appendix J.

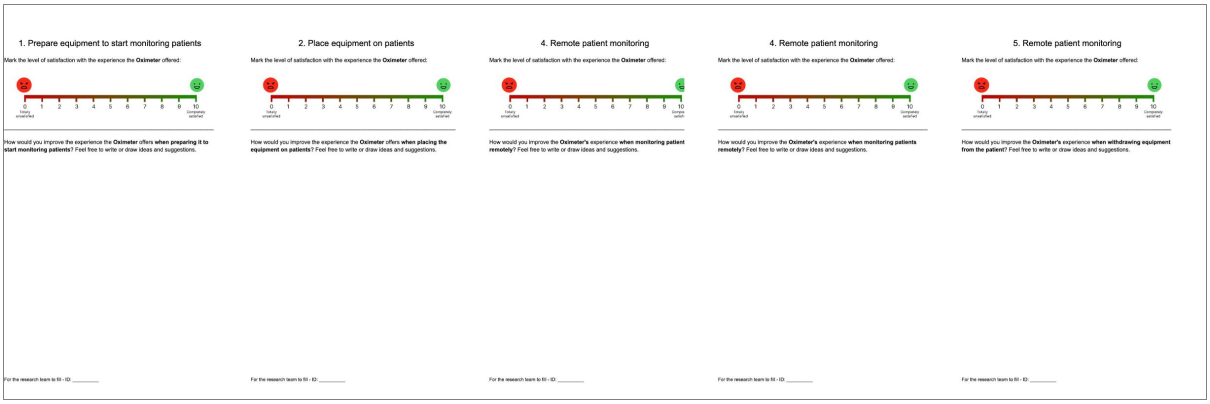


Figure 5.14: End of Journey Step Questionnaire Examples

Post-session questionnaire

Upon completing the last step of the user journey, participants are asked to answer one final question to rate their overall experience and provide additional opinions, feedback, and suggestions. For this last one, the questionnaire template needed to be adapted to include the OximeterIoT name. The adapted questionnaire can be seen in Figure 5.15.

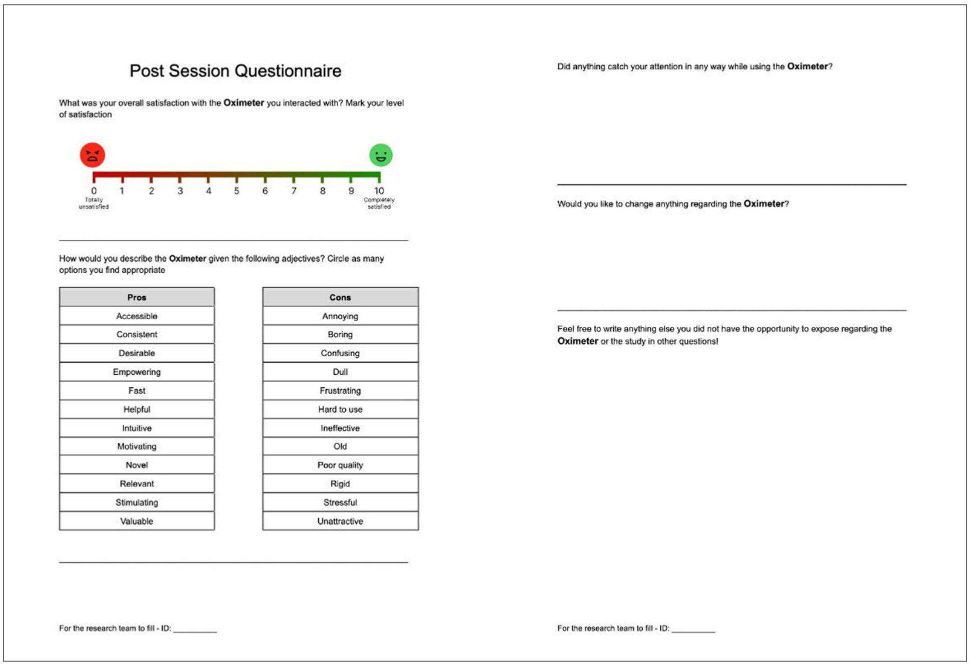


Figure 5.15: Post-session Questionnaire Example

5.5 Limitations and Conclusion

Building upon its previous iterations, the renewed version of ESE-TechProbe continues to support validation sessions, a critical component of the validated learning cycle in Lean methodology. These sessions are essential for gaining insights into the product and aligning it with user needs. Staying true to the original purpose of ESE-TechProbe, the updated version continues to emphasize the structured planning and execution of these sessions. Furthermore, modifications inspired by earlier implementations and from scientific evidence have been identified as valuable enhancements, contributing to the evolution and refinement of the technique.

In summary, the opportunities of improvement were regarding: the process, to incorporate activities to capture initial perception and provoke creativity for the co-creation aspect; instruments to assess users perception of the product; instruments to support researchers on using the technique and make notes during the studies; activities to do after the user interacts with the product and instrument to register the post-use perception and suggestions.

The identified opportunities for improvement enabled the proposal for the third version of the ESE-TechProbe. Table 5.7 sums the characteristics of the technique proposed in this chapter.

Although the renewed technique was designed based on evidence, one limitation can significantly impact its usage. The proposed technique focuses on in-person studies and does not support remote studies. Additionally, the technique targets contemporary software systems due to the uncertain environment in which they operate. However, it can be used on traditional systems.

Although empirical studies to evaluate the technique from the perspective of software engineering practitioners are still necessary, as done in the first version of the technique reported in Chapter 3.1.2, this study aimed to structure and present a new version of the technique. These primary studies can provide valuable feedback to evolve the technique to better meet the necessities of CSS development, representing an opportunity for future work.

The phases, activities, and instruments summarized in Table 5.7 reflect a structured and comprehensive technique for conducting validation sessions with Technology Probe. Each phase—from initial planning to post-study analysis—was strategically designed to capture valuable insights, ensure participant engagement, and facilitate iterative improvements to the product, aligning with the Technology Probe perspectives. By combining diverse instruments such as demographic forms, questionnaires, and observational notes, the methodology provided a rich understanding of the user experience across all moments of the study.

Table 5.7: Study Phases and Activities

Phase	**Purpose**	**Activities**	**Instruments**	**TP Perspective**
Pre-study	Plan and Organize the studies	Deploy the Probe, design user journey, adapt instruments for the study	None	None
Study: Pre-session	Set expectations & gather consent	Study explanation, brief probe explanation, get consent, capture participant preconceptions	Explanation material, informed consent questionnaire, questionnaire to gather initial impressions of the probe	Design
Study: Throughout the session	collect user impressions	follow the user journey steps, collect user experience and emotional reaction of them, take notes from the opinion verbalized by the participants during the think-aloud	Probe, observation notes, and questionnaires to assess the experience of each journey step	Social, Design and Egineering
Study: Post-session	Assess experience and gather feedback	Capture post-use perceptions	Final questionnaire to capture feedback and general user experience	Social and Design
Post-study	Summarize results	Analyze the collected data, consolidate improvements for the product	None	None

Chapter 6

Conclusion

Finally, this chapter focuses on presenting this dissertation's final considerations. It also discusses the limitations of this research and possible future works that emerge from the findings.

6.1 Final Considerations

This dissertation presented the process of evolving an existing Technology Probe technique, the ESE-TechProbe. The improvement process was based on empirical and scientific evidence collected through previous experiences with the technique and presented in the literature. The improved technique consists of a defined set of steps and instruments, which aim to enhance and ease the researcher's experience in applying the Technology Probe, specifically the ESE-TechProbe, in software engineering projects.

As seen previously, the development of contemporary software systems is marked by numerous challenges, one of which is the high level of uncertainty (Motta, 2018). This uncertainty results from the inability to easily access clients and end-users to design the software systems, as it is necessary to infer the requirements. This dissertation explores the use of the continuous validation process, encapsulated in the ESE-TechProbe, to guide CSS development, utilizing the validated learning cycle as a tool to mitigate these challenges. In the validated learning cycle, validation sessions are conducted to test simple versions of the product, such as a minimum viable product or a probe.

Validation sessions are often used in traditional software development. They help evaluate preliminary product versions with stakeholders, collecting feedback, user perception, and opportunities for improvement. These sessions happen *ad-hoc*, and the researcher must develop the session and instruments accordingly. Therefore, using the Technology Probe was seen as an opportunity to ease the planning of validation sessions, following a specified method.

Technology Probe is a co-creation method based on the concept of cultural probe. TP aims to co-create technology with potential users using a probe, a simple technological artifact similar to the technological product. Not only for co-creation, but TP is often used to evaluate the technology from the user perspective, being observant of three perspectives: (i) social, focusing on understanding user behaviors towards the technology; (ii) design, which wants to inspire user in co-create, providing insights for the technology; (iii) engineering, to collect the data on the probe functioning in a real-world setting.

Previous researchers from the ESE Laboratory identified similarities between the goals of validation sessions and the perspectives of the Technology Probe, recognizing the opportunity to utilize the TP method to guide validation sessions. However, the method doesn't present a structured application technique, leaving it up to the researcher to organize the TP session according to their goals. Within this perceived opportunity, researchers from the ESE Laboratory developed a structured Technology Probe technique, known as the ESE-TechProbe, to be applied in a real-world case of contemporary software development.

The first version of the ESE-TechProbe was used in the Delta Organization case. The Delta organization wanted to evaluate their software from the user perspective, to understand the product's user experience, collect feedback, and observe the product's behavior, searching for any failures. This version utilized instruments to capture the user's emotional reaction (Figure 3.2) and provided adjectives for the user to describe the product they interacted with (Table 3.1). The results from this experience were positive; it enabled the organization to gather user feedback and improve its product. Following a study conducted to evaluate the first version of the technique and gather feedback on the instruments used, the method evolved into a second version. This version was used to assess the OximeterIoT product, utilizing user journeys to help users immerse themselves in the context of use. Still, it used the faces (Figure 3.2) with open questions to capture the user's emotional reactions to the product. In this experience with OximeterIoT, opportunities for improvement were identified in the technique, beyond the product results. Therefore, this research aimed to propose an evolved ESE-TechProbe technique, presenting the third version. This third version aims to support researchers in utilizing TP during validation sessions while developing contemporary software systems.

To fulfill this goal and answer the question this dissertation had a design research based on the evidence based research: organize the perceived improvements from previous experiences; it was conducted a literature study, rapid review, to collect scientific evidence on the use and practices of Technology Probe in software development; aggregate the results from previous experiences and results from the rapid review; finally, the evolved technique was proposed.

From the previous experiences, three significant improvements were mapped: evolve the instrument to assess the emotional reaction, the smiley faces (Figure 3.2); improve the way users qualify their opinion of the product, in version one with a table of adjectives

(Table 3.1) and in the second version it was an open question, as seen in Figure 3.4; finally, from the report of the OximeterIoT version, it was seen the necessity of instruments to support researchers use the ESE-TechProbe.

The literature was reviewed using a rapid review protocol to gather scientific evidence and propose additional enhancements for the technique. The search for studies was conducted in the Scopus library, yielding 287 documents. Filters were applied, and 42 documents were selected for analysis. From these studies, it was possible to obtain a general overview of Technology Probe techniques and their usage in software development. The Appendix B shows a structured checklist summarizing the characteristics a Technology Probe technique must consider when being developed and proposed. This checklist analyzed the second version of the ESE-TechProbe, as presented in Chapter 5 section 5.1.2 the evolution opportunities perceived from the literature study mainly focused on structuring better instruments to assess user perception, easing the researcher's experience in using the technique, and propose instruments to capture user general opinion after interacting with the probe.

Therefore, the third version of ESE-TechProbe maintained the essence of its origins: a technique to be used in validation sessions. This version focuses on the development of contemporary software systems. It was structured to guide researchers in planning their validation session (Figure 5.2) and to provide another method for assisting them in conducting their session (Figure 5.3). Besides mapping the process, the proposal for the third version also includes a set of instruments to assess user perceptions and assist researchers in using the technique. Table 6.1 sums the instruments proposed.

Phase	**Instrument**	**Appendix**
Study: Pre-session	Explanation material Informed consent questionnaire Questionnaire to gather initial impressions of the probe	D C F
Study: Throughout the session	Observation notes Questionnaires to assess the experience of each journey step	E G
Study: Post-session	Final questionnaire to capture feedback and general user experience	H

Table 6.1: Study instruments and corresponding appendices

The result from this dissertation contributes to and highlights aspects discussed in the related work in Chapter 2.4. The ESE-TechProbe helps mitigate some reported challenges regarding validation sessions and continuous experimentation. For example, the third version of ESE-TechProbe provides a structured set of steps to be used, a challenge reported by TKALICH *et al.* (2025). Also, ANDERSON *et al.* (2022) and SOUZA *et al.* (2023) express the lack of tooling and technology to support continuous experimentation; the technique proposed in this dissertation is a tool to be used in the process of the validated learning cycle, a step within the continuous experimentation process.

The ESE-TechProbe allows an integration between user evaluation and the software development process. Studies ALZAYED and KHALFAN (2021) and SZABÓ and HERCEGFI (2023) reported the importance of this integration to achieve better software. Additionally, traditional HCI methods differ in their strategies for evaluating software from the user's perspective, such as questionnaires, observations, or interviews (Piedra, 2024). The ESE-TechProbe incorporates traditional methods to conduct the study and gather user feedback.

Regarding evaluating user experience in contemporary software systems, NTOA (2025) and CHENG *et al.* (2024) explore the possibilities of conducting UX evaluation in CSS and report difficulties in performing these evaluations. Therefore, the third version of the ESE-TechProbe aims to evaluate the user experience (UX) and other interesting aspects of CSS to promote their improvement.

This research lays the groundwork for applying ESE-TechProbe in future studies and further TP technique proposals by refining and advancing the use of Technology Probe in software engineering. The checklist presented in this work provides a structured guide that software engineers can use to propose meaningful techniques, aligned with past research. The method presented opens possibilities for systematically incorporating TP in the validated learning cycle.

6.2 Contributions

This dissertation aimed to evolve the ESE-TechProbe based on evidence, using results from previous experiences and the literature. Furthermore, organizing the body of knowledge of Technology Probe was crucial to identifying opportunities for the new version.

The problem to be addressed in this dissertation was the difficulty of applying validation sessions with Technology Probe in developing CSS. The ESE Group had already proposed the ESE-TechProbe, but it was seen that improvements were necessary. Therefore, the research question of this dissertation was: **What improvements observed in the state of the art can be introduced into an existing Technology Probe technique to support validation sessions of contemporary software systems products?** The results of previous experience and from the literature review were systematically analyzed, and the key improvements were mapped:

- Instruments to assess users' perception:
  - Capture user preconceptions of the product;
  - Encourage user creativity to promote co-creation and suggestions;
  - Gather users' emotional reactions about the probe, and;
  - Register users' general perception of the probe after interacting with it.
- Researchers' experience using the technique:
  - Structured process for researchers to follow to apply the technique in their validation sessions;
  - A script to follow in the study sessions;
  - Template for researchers to adapt when using the technique, and;
  - An instrument to assist researchers' note-taking, considering the Technology Probe characteristics.

This dissertation conducted a secondary study and developed a checklist to assess Technology Probe techniques, enabling the identification of key insights. Building upon these findings, the ESE-TechProbe technique was refined and evolved. The main contributions of this research can be summarized as follows:

- Analyze the previous experience of the ESE-TechProbe
  - Organize the body of knowledge of prior experiences of the ESE-TechProbe.
  - Sum the results from the experiences, focusing on improvements for the technique.
  - Luciana Nascimento, Larissa Galeno, Clinton Pessoa, Patricia Silva, and Guilherme Travassos. 2024. Uso de Technology Probe na Engenharia de Sistemas de Software para Saúde. In Anais do XXVII Congresso Ibero-Americano em Engenharia de Software, maio 06, 2024, Curitiba/PR, Brasil. SBC, Porto Alegre, Brasil, 211-225. DOI: https://doi.org/10.5753/cibse.2024.28449.
- Investigate existing Technology Probe techniques
  - It was necessary to characterize Technology Probe techniques used in different software systems development to obtain a general perspective of TP. From this general perspective, it would enable the research to compare the existing ESE-TechProbe with the other techniques.
  - A rapid literature review was conducted to identify techniques following a predefined study protocol.

- A set of characteristics was obtained and utilized to build the facets of the Technology Probe technique. These aspects were used to analyze the previous version of the ESE-TechProbe to obtain improvement opportunities. It was systematically structured in a checklist format available in Appendix B.

- Evolution of the ESE-TechProbe
  - Organization of the technique's process. It was structured as the process required to organize the study using the technique, and it detailed the steps to follow within a study session.
  - A set of instruments was designed to collect user perceptions of the probe, focusing on assessing the user experience, functionality, and gathering improvement suggestions.
  - A set of instruments was thought to improve the researcher's experience using the technique. One should guide the planning of the study, and another should assist with note-taking.

6.3 Limitations

Even though this work can result in valuable contributions to the software engineering community, there are some observed limitations:

- The literature study followed a Rapid Review protocol, meaning it focused its search on a single source of information, Scopus, and employed a limited search string due to the study's timeframe. For example, the search string did not include the term "co-design", as it would bring more documents than the researcher could handle.

- Additionally, the Rapid Review was conducted primarily by the author and revised by the supervisor, which may introduce bias into the selected articles.

- This dissertation does not present an experimental study to evaluate the evolved ESE-TechProbe technique with software engineers and practitioners. However, it focused on delivering structured instruments based on evidence or lessons learned from past experiences, solidifying the body of knowledge built on this dissertation.

- In the proposed instruments, the VAS scale (Figure 5.1) is used to assess the user's satisfaction with their experience using the probe. However, in experimental studies, it is necessary to evaluate this scale to determine whether it is a suitable instrument for capturing participants' reactions.

- Another aspect that needs to be observed in experimental studies is the behavior of participants when faced with numerous instruments to answer during their interaction with the probe. Having multiple questionnaires to answer can limit participants' creativity and cause boredom. When evaluating version 3, it is essential to consider this aspect.

6.4 Future Work

Some research opportunities were unexplored in this dissertation, and others emerged from the obtained results. Below are the candidates for further investigation:

- Development of experimental studies to evaluate the evolved ESE-TechProbe, verifying its acceptability and viability. It is valid to seek different samples, one from the academic perspective and the other from the software engineering market.
- In this proposal, it is a requirement to use the concept of a User Journey. However, the instruments do not facilitate the creation and design of such a journey. Therefore, it is possible to research and design an artifact that assists in creating a user journey, with a focus on the development of contemporary software systems.
- Analyze the possibility of improving the technique's instruments, for example, alongside the researchers' notes, to guide researchers in recording (video and audio) of the session, and also to enhance the instrument to capture the user's emotional reaction.
- Although some studies utilize the Technology Probe to elicit specifications for their system, there remains an opportunity to understand and design a deeper connection between the results of the TP and requirements engineering.
- The use of Large Language Models (LLM) can assist the use of Technology Probe in diverse ways; either way, there is still a need for deep research:
  - Use of LLM to simulate participants, giving the LLM enough context of your participant, and asking it to fill in the instruments. In this option, it is possible to analyze the use of LLM to perform pilot studies before the experiment session to check if the instruments are correct.
  - Use of LLM to help organize the Technology Probe to be employed, organizing the session flow of activities, designing the user journey, filling the template instruments, and assisting researchers on the study organization.
  - Use of LLM as a helper to analyze data; one option to help translate the TP results into software requirements.

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Appendix A

Select studies of the literature review

Table A.1: Selected Studies

ID	Authors	Title	Year	Citation
S1	Naseem M.; Younas F.; Mustafa M.	Designing Digital Safe Spaces for Peer Support and Connectivity in Patriarchal Contexts	2020	NASEEM *et al.* (2020)
S2	Li Z.; Feng L.; Liang C.; Huang Y.; Fan M.	Exploring the Opportunities of AR for Enriching Storytelling with Family Photos between Grandparents and Grandchildren	2023	LI *et al.* (2023)
S3	Felberbaum Y.; Lanir J.; Weiss P.L.	Designing Mobile Health Applications to Support Walking for Older Adults	2023	FELBERBAUM *et al.* (2023)
S4	Crabtree A.; Hyland L.; Colley J.; Flintham M.; Fischer J.E.; Kwon H.	Probing IoT-based consumer services: 'insights' from the connected shower	2020	CRABTREE *et al.* (2020)
S5	Vyas D.; Halloluwa T.; Heinzler N.; Zhang J.	More than step count: designing a workplace-based activity tracking system	2020	VYAS *et al.* (2020)
S6	Haldar S.; Kim Y.; Mishra S.R.; Hartzler A.L.; Pollack A.H.; Pratt W.	The Patient Advice System: A Technology Probe Study to Enable Peer Support in the Hospital	2020	HALDAR *et al.* (2020)

ID	Authors	Title	Year	Citation
S7	Segura E.M.; Vidal L.T.; Bel L.P.; Waern A.	Using training technology probes in bodystorming for physical training	2019	SEGURA *et al.* (2019)
S8	Han H.L.; Renom M.A.; MacKay W.E.; Beaudouin-Lafon M.	Textlets: Supporting Constraints and Consistency in Text Documents	2020	HAN *et al.* (2020)
S9	Chandrasekaran V.; Banerjee S.; Mutlu B.; Fawaz K.	PowerCut and obfuscator: An exploration of the design space for privacy-preserving interventions for smart speakers	2021	CHANDRASEKARAN *et al.* (2021)
S10	Gough P.; Kocaballi A.B.; Naqshbandi K.Z.; et al.	Co-designing a Technology Probe with Experienced Designers	2021	GOUGH *et al.* (2021)
S11	Flynn A.; Barry M.; Qi Koh W.; Reilly G.; et al.	Introducing and Familiarising Older Adults Living with Dementia and Their Caregivers to Virtual Reality	2022	FLYNN *et al.* (2022)
S12	Narkar S.; Zhang Y.; Liao Q.V.; Wang D.; Weisz J.D.	Model LineUpper: Supporting Interactive Model Comparison at Multiple Levels for AutoML	2021	NARKAR *et al.* (2021)
S13	Zhou Q.; Grebel L.; Irlitti A.; Minaai J.A.; Goncalves J.; Velloso E.	Here and Now: Creating Improvisational Dance Movements with a Mixed Reality Mirror	2023	ZHOU *et al.* (2023a)
S14	Graf M.; Barthet M.	Mixed Reality Musical Interface: Exploring Ergonomics and Adaptive Hand Pose Recognition for Gestural Control	2022	ZHOU *et al.* (2023b)
S15	Arora S.; Jin Q.; Yarosh S.	Exploring Embodied Approaches for Large Age Gap Sibling Communication through Technology Probes	2023	ARORA *et al.* (2023)

ID	Authors	Title	Year	Citation
S16	Oh H.; Pontis S.	Understanding individuals with spinal cord injury's self-care practices: a technology probe study to promote pressure relief adherence	2023	OH and PONTIS (2024)
S17	Huang K.; Sun R.; Zhang X.; et al.	WovenProbe: Probing Possibilities for Weaving Fully-Integrated On-Skin Systems Deployable in the Field	2021	HUANG *et al.* (2021)
S18	Seah S.A.; Obrist M.; Roudaut A.; Subramanian S.	Need for touch in human space exploration: Towards the design of a morphing haptic glove – exoskin	2015	SEAH *et al.* (2015)
S19	Kulp L.; Sarcevic A.; Farneth R.; Ahmed O.; Mai D.; Marsic I.; Burd R.S.	Exploring design opportunities for a context-adaptive medical checklist through technology probe approach	2017	KULP *et al.* (2017)
S20	Ten Bhömer M.; Van Den Hoven E.	Interaction design for supporting communication between Chinese sojourners	2013	TEN BHÖMER and VAN DEN HOVEN (2013)
S21	Kirk D.S.; Durrant A.; Wood G.; Leong T.W.; Wright P.	Understanding the sociality of experience in mobile music listening with Pocketsong	2016	KIRK *et al.* (2016)
S22	Marcu G.; Dey A.K.; Kiesler S.	Parent-driven use of wearable cameras for autism support: A field study with families	2012	MARCU *et al.* (2012)
S23	Quintana R.; Quintana C.; Madeira C.; Slotta J.D.	Keeping watch: Exploring wearable technology designs for k-12 teachers	2016	QUINTANA *et al.* (2016)
S24	Chidziwisano G.H.; Wyche S.	M-Kulinda: Using a sensor-based technology probe to explore domestic security in rural Kenya	2018	CHIDZIWISANO and WYCHE (2018)
S25	Paay J.; Nielsen H.; Larsen H.; Kjeldskov J.	Happy bits: Interactive technologies helping young adults with low self-esteem	2018	PAAY *et al.* (2018)

ID	Authors	Title	Year	Citation
S26	Grosinger J.; Vetere F.; Fitzpatrick G.	Agile life: Addressing knowledge and social motivations for active aging	2012	GROSINGER *et al.* (2012)
S27	Ding X.; Jiang Y.; Qin X.; Chen Y.; Zhang W.; Qi L.	Reading face, reading health: Exploring face reading technologies for everyday health	2019	DING *et al.* (2019)
S28	De Freitas A.A.; Nebeling M.; Chen X.; Yang J.; Ranithangam A.S.K.K.; Dey A.K.	Snap-To-It: A user-inspired platform for opportunistic device interactions	2016	DE FREITAS *et al.* (2016)
S29	Palay J.; Newman M.	SuChef: An in-kitchen display to assist with "everyday" cooking	2009	PALAY and NEWMAN (2009)
S30	Mahmud A.A.; Gerits R.; Martens J.-B.	XTag: Designing an experience capturing and sharing tool for persons with aphasia	2010	AL MAHMUD *et al.* (2010)
S31	Riche Y.; Simpson M.; Viller S.	Zebra: Exploring users engagement in fieldwork	2008	RICHE *et al.* (2008)
S32	Langdale G.; Kay J.; Kummerfeld B.	Using an intergenerational communications system as a 'lightweight' technology probe	2006	LANGDALE *et al.* (2006)
S33	Wyeth P.; Diercke C.; Viller S.	Design for inspiration: Children, personal connections and educational technology	2006	WYETH *et al.* (2006)
S34	Dawe M.	"let me show you what i want": Engaging individuals with cognitive disabilities and their families in design	2007	DAWE (2007)

ID	Authors	Title	Year	Citation
S35	Hutchinson H.; Mackay W.; Westerlund B.; Bederson B.B.; Druin A.; Plaisant C.; Beaudouin-Lafon M.; Conversy S.; Evans H.; Hansen H.; Roussel N.; Eiderbäck B.; Lindquist S.; Sundblad Y.	Technology probes: Inspiring design for and with families	2003	HUTCHINSON *et al.* (2003)
S36	Jörke M.; Sefidgar Y.S.; Massachi T.; Suh J.; Ramos G.	Pearl: A Technology Probe for Machine-Assisted Reflection on Personal Data	2023	JÖRKE *et al.* (2023)
S37	Hope Chidziwisano G.; Mariakakis A.; Wyche S.; Mafeni V.; Gideon Banda E.	NkhukuProbe: Using a Sensor-Based Technology Probe to Support Poultry Farming Activities in Malawi	2021	HOPE CHIDZIWISANO *et al.* (2021)
S38	Wong E.; Esquivel J.S.; Leiva G.; Grønbæk J.E.; Velloso E.	Practice-informed Paterns for Organising Large Groups in Distributed Mixed Reality Collaboration	2024	WONG *et al.* (2024)
S39	Hu Y.; Stegner L.; Kotturi Y.; Zhang C.; Peng Y.-H.; Huq F.; Zhao Y.; Bigham J.P.; Mutlu B.	”This really lets us see the entire world:” Designing a conversational telepresence robot for homebound older adults	2024	HU *et al.* (2024)

ID	Authors	Title	Year	Citation
S40	Lu Y.; Zhang C.; Yang Y.; Yao Y.; Li T.J.-J.	From Awareness to Action: Exploring End-User Empowerment Interventions for Dark Patterns in UX	2024	LU *et al.* (2024)
S41	Lee S.; Hwang S.; Oakley I.; Lee K.	Expanding the Design Space of Computer Vision-based Interactive Systems for Group Dance Practice	2024	LEE *et al.* (2024)
S42	Benhamida L.; Larabi S.; Metatla O.	Hapstick-Figure: Investigating the Design of a Haptic Representation of Human Gestures from Theater Performances for Blind and Visually-Impaired People	2024	BENHAMIDA *et al.* (2024)

Appendix B

Technology Probe Technique Checklist

Table B.1: TP Checklist

Facets	**Characteristic**	**Checklist**	**Details**
Expectations	Motivation to use TP	What is the motivation behind your TP technique? Choose one or more: ( ) elicit design features ( ) evaluate feasibility ( ) collect feedback ( ) gather insights and ideas ( ) discover unintended uses ( ) reveal new technologies ( ) promote participation in co-design ( ) realize real-world challenges ( ) perceive user reality ( ) recognize user perception	Observations
	Outcomes	What outcomes your technique aims to have? Choose one or more: ( ) design recommendations ( ) new ideas for the probe ( ) user context ( ) user experience ( ) user feedback ( ) specifications	Observations

Facets	Characteristic	Checklist	Details
	Positive Aspects	What are the positive aspects from TP your technique takes advantage? Choose one or more: ( ) knowledge sharing ( ) open-endness ( ) real-world comprehension ( ) use of simple probes ( ) participant engagement	Observations
Organization	TP Study Components	What are the study components your study aims to have? Choose none, one or more: ( ) participation reward ( ) study organization ( ) iteration with probe ( ) probe usage helper ( ) interpretative data analysis ( ) procedure monitoring	List here other components
	TP Session Runtime	Your TP technique aims in lasting: ( ) days ( ) hours ( ) weeks	Observations
Obstacle	Challenges	What are the challenges you foresee your technique facing? Choose none, one or more: ( ) deploying the probe ( ) participant recruitment ( ) user profile ( ) encouraging participation ( ) execution tangibility ( ) understanding the probe ( ) broad space of solutions	How do you intend to mitigate those challenges?
Requirements	Probe	What is the piece of technology being submitted into evaluation? Choose one or more: ( ) Hardware-based Probe ( ) Non-technological Probe ( ) Software-based Probe	Observations

Facets	Characteristic	Checklist	Details
	Pre-TP Session	What are the activities to be done before the participant interacts with the Probe? Choose one or more: ( ) explanation of the study ( ) familiarization with the probe ( ) informed consent ( ) explanation of the probe ( ) pre-use questionnaire ( ) pre-use interview	Observations
	Data Collection Strategy	What will be the chosen strategy the technique will use to collect data? Choose one or more: ( ) participant diary logging ( ) researcher field notes ( ) probe log data ( ) participants think-aloud ( ) throughout-study interview ( ) end-user suggestions	Observations
	Observation Strategy	What will be the chosen strategy the technique will use to observe participants? Choose one or more: ( ) task execution ( ) participatory design workshop ( ) open-ended probe interaction ( ) end-user sketching	Observations
	Post-TP Session	What are the activities to be done after the participant interacts with the Probe? Choose one or more: ( ) post-use follow-up interview ( ) post-use follow-up questionnaire	Observations

Appendix C

Informed Consent Questionnaire

Informed Consent Form (ICF)

I declare that I am over 18 years old and agree to participate in studies conducted by *<include research team name/research team responsible>* from *<research team should specify the laboratory/ university>*. These studies aim to understand software technology's feasibility, viability, and experience using the Technology Probe methodology.

Procedures

Various software technologies may be presented. I understand that I will be taught how technology works and asked to use it during the session organized by the researcher. In this session, some experimental methods will be applied, and I will be asked to complete some tasks to reflect on their use and evaluate them. I understand that once the session has ended, the opinions I expressed and the questionnaires I answered will be studied to understand the aspects of the software technology presented to me.

The researcher will conduct the study by collecting, analyzing, and reporting data collected throughout the session. I understand that I am not obligated to provide information regarding my performance in the session and that I may request the removal of my results from the study at any time without penalty. I understand that there will be no reward for participating in this study and that my decision not to participate will not negatively impact me. I also understand that once the data is collected and analyzed, my name will be removed from the data and will not be used during the analysis or in the presentation of the results.

Confidentiality

All information collected in this study is confidential and follows the principles of *<research team should specify applicable data protection regulations, e.g., GDPR, LGPD>*. My name will not be identified at any time. Likewise, I commit not to disclose my results until the study is completed and to maintain confidentiality regarding the techniques and documents presented that are part of the experiment.

Benefits and Right to Withdraw

I understand that this study does not pose any personal risk and that the benefits I will receive from participating are limited to learning about the proposed software technology. However, the researchers hope to gain insights into the software technology's feasibility, viability, and experience.

I understand that I am free to ask questions at any time or request that any personal information related to me not be included in the study. I am participating voluntarily, solely to contribute to the advancement and development of software technology.

Responsible

<complete with the name of the research team responsible>
<complete with the person affiliation>

Consent Statement

By signing below, you acknowledge that you have read and understood this form and voluntarily agree to participate in the study.

Participant's Name: ____

Signature: ____

Date: ____

For the research team to fill - **ID**: ____________________

Appendix D

Basic Steps

Basic Steps of

ESE-TechProbe

Authors

Larissa Galeno
Guilherme Horta Travassos

Proposal

Tutorial on how to use and adapt ESE-TechProbe, a technique based on Technology Probe

Focus

Software engineers

1

Table of Contents

Overview

The ESE-TechProbe is based on the Technology Probe method and crafted for validation sessions. The technique is adequate if you are looking for a way to validate a technology proposal with end users, understand the user experience, and collect their feedback. The technique focuses on extracting results with sessions over a couple of hours and uses strategies to immerse the users in the context of technology use. The present document shows a couple of steps to apply for the ESE-TechProbe.

Step 0 – Is the ESE-TechProbe what you need?

Before planning and preparing your study, it is important to understand if this technique aligns with your goals. The next sections present questions to guide your decision.

What are your Motivations?

The ESE-TechProbe is an interesting approach if the research team is interested in gathering data regarding one of these aspects: eliciting design features, evaluating the technology's feasibility, collecting user feedback, gathering insights and ideas from the users, discovering unintended uses of the technology, or perceiving user reality.

What outcomes do you expect?

Using the ESE-TechProbe, diverse qualitative data regarding the proposed technology and the end-users can be gathered, specifically regarding the user experience, user feedback, and a list of specifications for improvements and requirements for the proposed technology.

Keep in mind some challenges.

Due to the Technology Probe's nature, the technique poses some challenges—for example, the engagement of end users and participation recruitment. The execution can also represent a challenge, maybe from the user profile or the time frame available for the evaluation. The ESE-TechProbe uses the user journey to mitigate this challenge, trying to immerse the user faster in the context to collect data about the probe in hours at most.

Step 1 – Planning the TP Session

1.1 Deploy the Probe

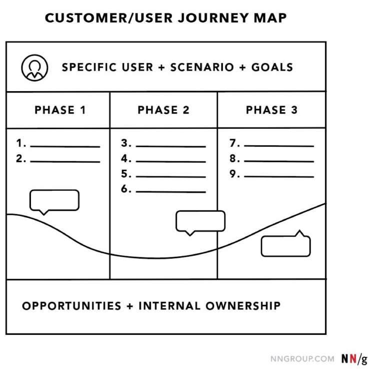
It is essential to have a ***Probe***, an artifact you want to validate and discover user features. This probe can be technological (including software and/or hardware components) or non-technological (an abstraction of an idea you want to validate). Regardless of its nature, this probe needs to be ready for use so that users can interact with it. How it will be deployed is up to the research team.

1.2 Design User Journey

Given the necessity of immersing the participants in the reality of using the probe and the challenge of doing this in a validation session that lasts an hour, it is important to find ways to deal with this, such as user journeys. User journeys enable the participants to immerse themselves in a specific context of usage in a limited timeframe, allowing them to focus on one activity at a time.

It is important to be transparent to the participants at each step of their journey so they can fulfill the tasks and follow the think-aloud protocol accordingly. Finally, at the end of each journey step, they must complete a questionnaire that assesses their experience at that specific step and asks for suggestions to improve the process.

The following image shows the sequential structure of the user journey.



1.3 Prepare explanation material

The first step in the meeting with the participants is to explain the context in which the proposed technology (the probe) will be used. It is necessary to be cautious not to give much information about the probe to not bias the participants' ideas and suggestions. Then, it is imperative to prepare material (slides presentation, document..., etc.) to present this context to users. Also, it is important to explain the steps of the user journey the participants will go through.

1.4 Adequate Questionnaires

To collect the participant's perception, a collection of anonymous questionnaires is essential in different phases of the study: before the participant interacts with the probe (pre-session), after each step of the user journey (throughout the study), and when the interaction with the probe ends (post-session questionnaire).

1.4.1 Pre-session questionnaires

The pre-session questionnaire aims to collect consent from the participants, their demographic information (if the research team finds it interesting), and, most importantly, collect the participants' expectations regarding the probe. This questionnaire should be used after a brief explanation about the probe is given so that when participants are asked about their expectations, they have something to support their ideas.

The aim of asking their expectations is to promote creativity so that the researcher can use their answers to improve the technology.

An example of informed consent is seen in: Informed consent Form

An example of this questionnaire is seen in: Pre-session questionnaire

1.4.2 Throughout study questionnaires

The session will follow the user journey that was previously mapped, so whenever a step is completed, the participants should complete a questionnaire to assess their experience in the specific step (using the visual analogue scale) and reflect on improvements in the experience. The first question aims to understand the user's feelings and feedback about the usage of the probe, while the second wants to stimulate their creativity on the use of the proposed technology.

An example of the questionnaire can be seen in: Post journey step questionnaire

1.4.3 Post-session questionnaires

After the end of the user journey, the participants will be asked to answer a questionnaire to assess their opinions regarding the probe. At first, ask them to rate their overall experience with the probe. Then, they should qualify the technological proposal using a set of adjectives for them to choose. Finally, there will be open questions to catch positive and constructive feedback. Finally, there will be an open field for participants to write any final consideration they may have.

An example of the questionnaire can be seen in: Post-session questionnaire

1.5 Define Data Collection Strategy

Although the Technology Probe methodology leaves it up to the researchers to choose the strategy, the ESE-TechProbe uses a set of qualitative data: researcher filed notes gathered by their observation, annotations, and recordings of the participant's think-aloud and the data collected by the questionnaires, mostly end-user suggestions and ideas. In the case of a technological probe, using the probe log data to triangulate with the other data is valuable.

To help the researchers make their field notes, an instrument can be used keeping in mind the goals and aspects of Technology Probe (social, design, and engineering): researcher notes

1.6 Define Observation Strategy

The ESE-TechProbe proposes two options to guide the observation: **task execution** or **open-end probe interaction**. The first one can be applied given specific tasks for the participants to complete in each step of the journey, while the second one the participants use freely to complete the goal of the journey step.

Step 2 – Technology Probe Execution

After the planning, it's time to put into practice and execute the Technology Probe using the ESE-TechProbe. The arrangement of the study consists of three phases: pre-session, the session (moment of the participant intersecting with the probe using the think-aloud protocol) and the post-session. Further, the actions for each phase will be detailed.

2.1 Pre-session

The pre-session is a moment to align expectations with users. First, there should be an explanation of the probe, not giving too many details. Then, the participants should agree to the informed consent, answer the demographic questions, and register their expectations for the probe (that's why it shouldn't be given too much information about the probe at first). Finally, the researchers can explain the study's goal, presenting the user journey the user will go through for the next hour.

The researcher must remember to fill in the participant ID on the informed consent form and the subsequent form accordingly. This way, it will be possible to keep track of answers.

2.2 Interacting with the Probe

Then a designated researcher should guide the session so that the interaction of the participants with the probe follows the goal of each step of the user journey. At this point, it's important to observe participant's actions and listen to their opinions while they do the think-aloud. Also, at the end of a step from the user journey, it is necessary to give some time for participants to answer the questionnaire.

2.3 Post-session

When the participants complete the user journey, there is a final step to end the meeting. Ask participants to answer the final questionnaire to gather and compile their opinions and perceptions.

Step 3 – Post Technology Probe

After the execution of the study is time to analyze the data. Since the nature of the data collected from Technology Probe is qualitative, approaches to analyze it are interpretative data analysis or thematic analysis. It is up to the research team to choose their strategy. It is only important to keep in mind that the focus of the TP is to gather participant's feelings, experiences, suggestions and perceptions, being a method that focuses on the qualitative aspect.

The results of the ESE-TechProbe are mainly user feedback and an understatement of user experience. This can generate a list of technological proposal improvements or software requirements.

Conclusion

We hope this tutorial helps using the ESE-TechProbe and contribute to a better understanding of the Technology Probe Methodology. For questions and suggestions, please contact: galeno@cos.ufrj.br.

Related Institutions:

Further Information

NASCIMENTO, Luciana; GALENO, Larissa; PESSOA, Clinton Hudson; SILVA, Patricia Furtado; TRAVASSOS, Guilherme Horta. Uso de Technology Probe na Engenharia de Sistemas de Software para Saúde. In: CONGRESSO IBERO-AMERICANO EM ENGENHARIA DE SOFTWARE (CIBSE), 27. , 2024, Curitiba/PR. Anais [...]. Porto Alegre: Sociedade Brasileira de Computação, 2024 . p. 211-225. DOI: https://doi.org/10.5753/cibse.2024.28449.

Appendix

Below will be described the questionnaires to used and adapted:

1. Informed Consent Form (ICF)
2. Pre-session Questionnaire
3. Post-Journey Step Questionnaire
4. Post-session Questionnaire
5. Researcher Notes

It can also be download from:
https://ese-techprobe.vercel.app/documents.html

Informed Consent Form (ICF)

I declare that I am over 18 years old and agree to participate in studies conducted by <include research team name/research team responsible> from <research team should specify the laboratory/ university>. These studies aim to understand software technology's feasibility, viability, and experience using the Technology Probe methodology.

Procedures

Various software technologies may be presented. I understand that I will be taught how technology works and asked to use it during the session organized by the researcher. In this session, some experimental methods will be applied, and I will be asked to complete some tasks to reflect on their use and evaluate them. I understand that once the session has ended, the opinions I expressed and the questionnaires I answered will be studied to understand the aspects of the software technology presented to me.

The researcher will conduct the study by collecting, analyzing, and reporting data collected throughout the session. I understand that I am not obligated to provide information regarding my performance in the session and that I may request the removal of my results from the study at any time without penalty. I understand that there will be no reward for participating in this study and that my decision not to participate will not negatively impact me. I also understand that once the data is collected and analyzed, my name will be removed from the data and will not be used during the analysis or in the presentation of the results.

Confidentiality

All information collected in this study is confidential and follows the principles of <research team should specify applicable data protection regulations, e.g., GDPR, LGPD>. My name will not be identified at any time. Likewise, I commit not to disclose my results until the study is completed and to maintain confidentiality regarding the techniques and documents presented that are part of the experiment.

Benefits and Right to Withdraw

I understand that this study does not pose any personal risk and that the benefits I will receive from participating are limited to learning about the proposed software technology. However, the researchers hope to gain insights into the software technology's feasibility, viability, and experience.

I understand that I am free to ask questions at any time or request that any personal information related to me not be included in the study. I am participating voluntarily, solely to contribute to the advancement and development of software technology.

Responsible

<complete with the name of the research team responsible>

<complete with the person affiliation>

Consent Statement

By signing below, you acknowledge that you have read and understood this form and voluntarily agree to participate in the study.

Participant's Name: ____

Signature: ____

Date: ____

For the research team to fill - **ID**: ____________________

Pre-session Questionnaire

Demographic questions

(examples of demographic questions that can be used in this session)

What is your age?

( ) 18–24 ( ) 25–34 ( ) 35–44 ( ) 45–54 ( ) 55+

What is your gender?

( ) Male ( ) Female ( ) Prefer not to say

( ) Other: ______________________________

What is your highest level of education?

( ) Primary Education ( ) Secondary Education ( ) Higher Education

( ) Other: _____________________________

How familiar are you with tools like…? *(describe a similar tool to your probe)*

( ) Not familiar ( )Somewhat familiar ( ) Familiar ( ) Very familiar

---

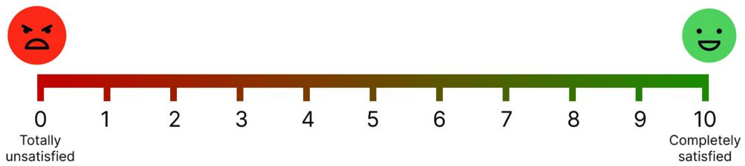
Expectations

After hearing the explanation about the study context, tell us what your expectations are regarding the technology and its usage:

For the research team to fill - **ID**: _______________________

Post-Journey Step Questionnaire <Complete with Journey Step Name>

Mark the level of satisfaction with the experience the *<complete with probe name>* offered:



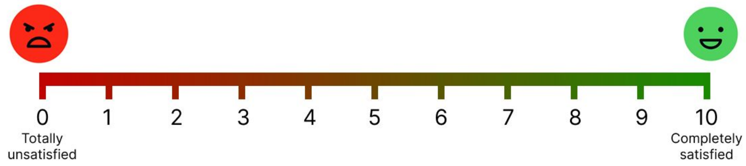
____

How would you improve the experience the <complete with probe name> offers for this moment? Feel free to write or draw ideas and suggestions.

For the research team to fill - **ID**: ____________________

Post-session Questionnaire (1)

What was your overall satisfaction with the <complete with probe name> you interacted with? Mark your level of satisfaction



Given the following adjectives, how would you describe the *<complete with probe name>*? Circle as many options you find appropriate

Pros
Accessible
Consistent
Desirable
Empowering
Fast
Helpful
Intuitive
Motivating
Novel
Relevant
Stimulating
Valuable

Cons
Annoying
Boring
Confusing
Dull
Frustrating
Hard to use
Ineffective
Old
Poor quality
Rigid
Stressful
Unattractive

For the research team to fill - **ID**: ___________________

Post-session Questionnaire (2)

Did anything catch your attention in any way while using the *<complete with probe name>*?

Would you like to change anything regarding the *<complete with probe name>*?

Feel free to write anything else you did not have the opportunity to expose regarding the *<complete with probe name>* or the study in other questions!

For the research team to fill - **ID**: ____________________

Researcher Notes (1)

Social (user experience; user feedback; user behaviors)
Design (co-creation; user suggestions)
Engineering (probe must be working properly; probe malfunction)

Researcher: ____________________________________

Researcher Notes (2)

Space for free annotations:

Researcher: ____

Appendix E

Researcher Notes

Researcher: ______________________________

Taking Notes on Technology Probe Session

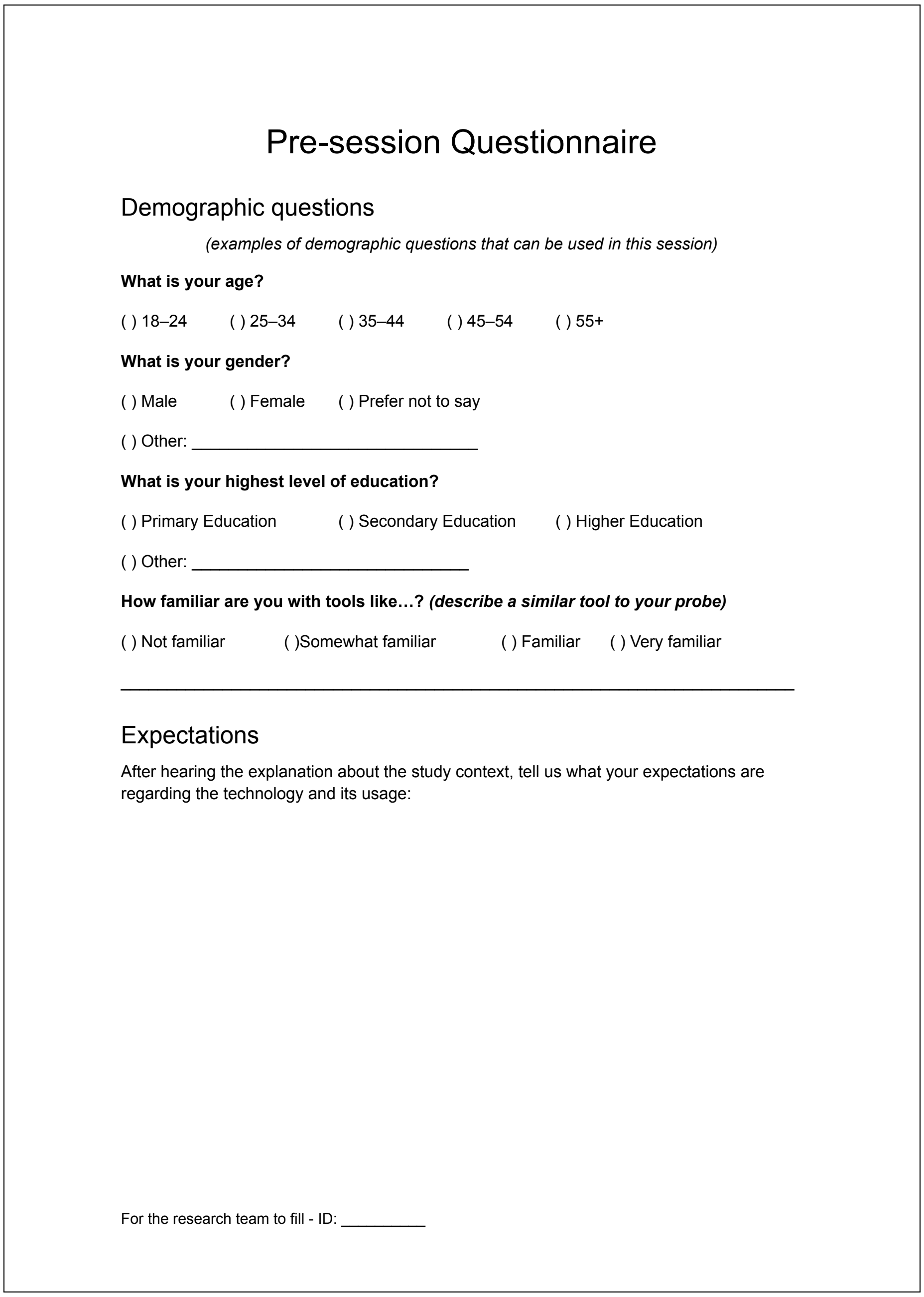
Social (user experience; user feedback; user behaviors)
Design (co-creation; user suggestions)
Engineering (probe must be working properly; probe malfunction)

Researcher: ____

Space for free annotations:

Appendix F

Pre-session Questionnaire



Pre-session Questionnaire

Demographic questions

(examples of demographic questions that can be used in this session)

What is your age?

( ) 18–24 ( ) 25–34 ( ) 35–44 ( ) 45–54 ( ) 55+

What is your gender?

( ) Male ( ) Female ( ) Prefer not to say

( ) Other: ______________________________

What is your highest level of education?

( ) Primary Education ( ) Secondary Education ( ) Higher Education

( ) Other: ______________________________

How familiar are you with tools like…? *(describe a similar tool to your probe)*

( ) Not familiar ( )Somewhat familiar ( ) Familiar ( ) Very familiar

---

Expectations

After hearing the explanation about the study context, tell us what your expectations are regarding the technology and its usage:

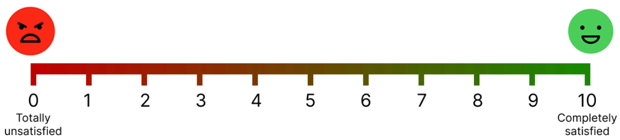
For the research team to fill - ID: __________

Appendix G

Throughout the Session Questionnaire

<Complete with Journey Step Name>

Mark the level of satisfaction with the experience the <*complete with probe name*> offered:



How would you improve the experience the <*complete with probe name*> offers for this moment? Feel free to write or draw ideas and suggestions.

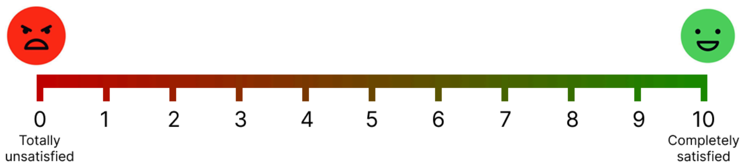
For the research team to fill - ID: __________

Appendix H

Post-Session Questionnaire

Post Session Questionnaire

What was your overall satisfaction with the <*complete with probe name*> you interacted with? Mark your level of satisfaction



Given the following adjectives, how would you describe the <*complete with probe name*>? Circle as many options you find appropriate

Pros
Accessible
Consistent
Desirable
Empowering
Fast
Helpful
Intuitive
Motivating
Novel
Relevant
Stimulating
Valuable

Cons
Annoying
Boring
Confusing
Dull
Frustrating
Hard to use
Ineffective
Old
Poor quality
Rigid
Stressful
Unattractive

For the research team to fill - ID: __________

Did anything catch your attention in any way while using the *<complete with probe name>*?

Would you like to change anything regarding the *<complete with probe name>*?

Feel free to write anything else you did not have the opportunity to expose regarding the *<complete with probe name>* or the study in other questions!

For the research team to fill - ID: __________

Appendix I

Session Introduction

Validation of an Oximeter

MSc Student
Larissa Galeno
galeno@cos.ufrj.br

Supervisor
Guilherme Horta Travassos
ght@cos.ufrj.br

Technology Proposal and Study

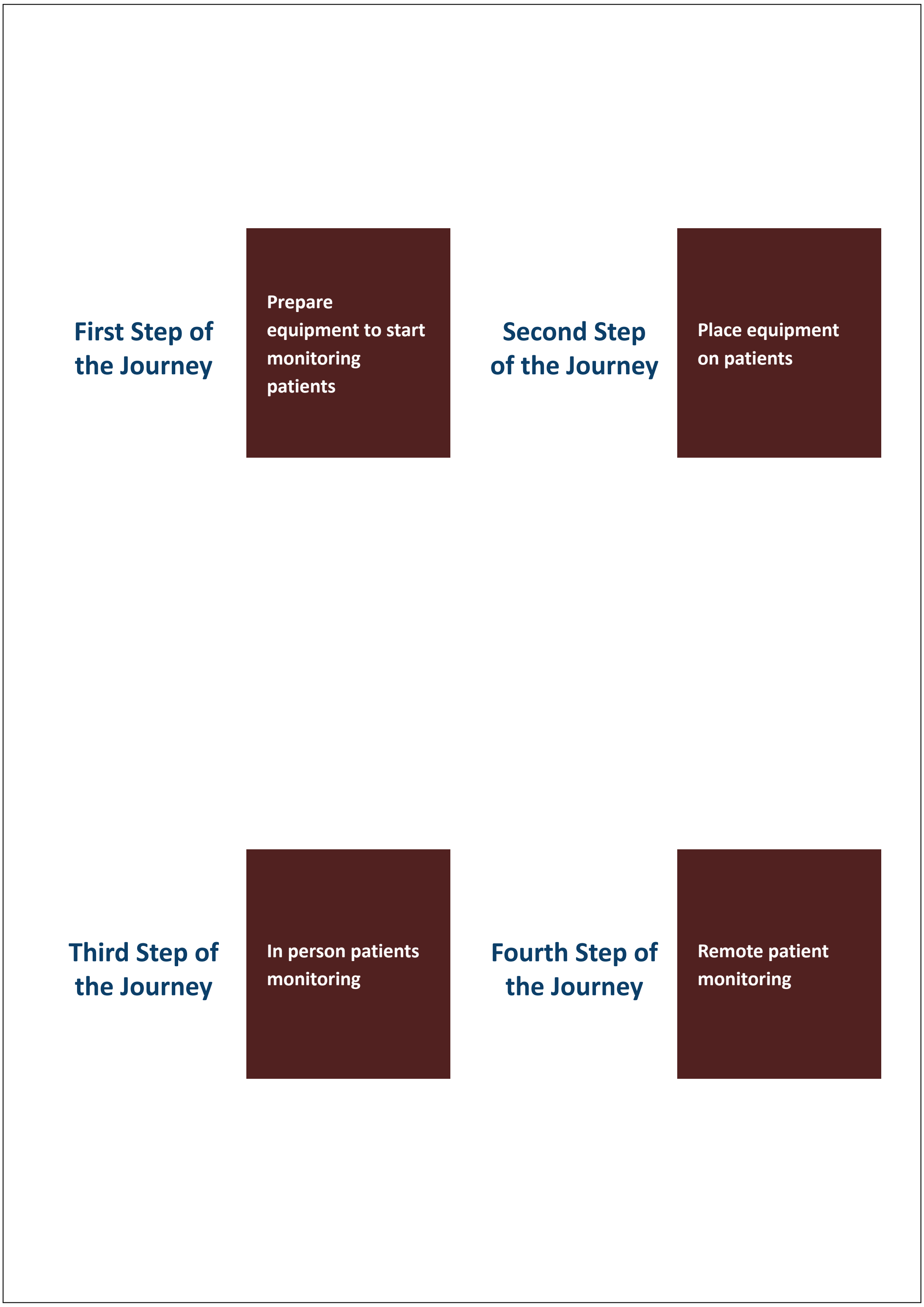
- You will be interacting with a Oximeter
  - An oximeter aims in measuring the amount of oxygen in your blood
- Throughout our conversation we hope to hear your **ideas, suggestions and feedbacks** about the oximeter
- You will be asked to prompt your opinion verbally and answer a couple of questionnaires
  - Have you signed the informed consent questionnaire?

What to expect from the session?

- You will be interacting with a Oximeter
- You will follow the steps of the oximeter usage, following a journey while using the Oximeter
  - While using it, please express every opinion that you have!

J1 Prepare equipment to start monitoring patients
J2 Place equipment on patients
J3 In person patients monitoring
J4 Remote patient monitoring
J5 Withdrawal equipment from patient

But before,
Please fill the Demographic questionnaire


First Step of the Journey
Prepare equipment to start monitoring patients
Second Step of the Journey
Place equipment on patients
Third Step of the Journey
In person patients monitoring
Fourth Step of the Journey
Remote patient monitoring

Fifth Step of the Journey

Withdrawal equipment from the patient

Conclusion

- After interacting with the equipment, what are your thoughts?
- Please, fill the post use questionnaire

Validation of an Oximeter

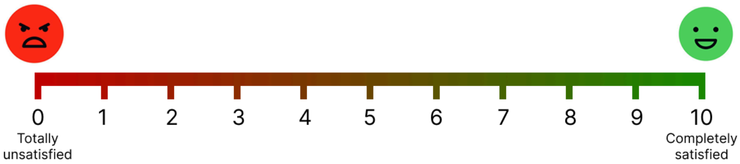
Thanks!

Appendix J

Throughout the Session Questionnaire – Example

1. Prepare equipment to start monitoring patients

Mark the level of satisfaction with the experience the **Oximeter** offered:

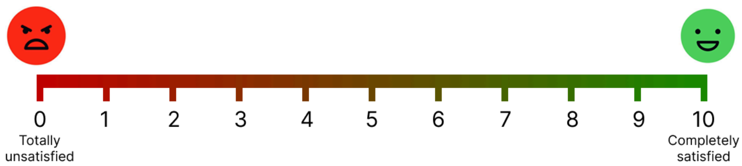


How would you improve the experience the **Oximeter** offers **when preparing it to start monitoring patients**? Feel free to write or draw ideas and suggestions.

For the research team to fill - ID: __________

2. Place equipment on patients

Mark the level of satisfaction with the experience the **Oximeter** offered:

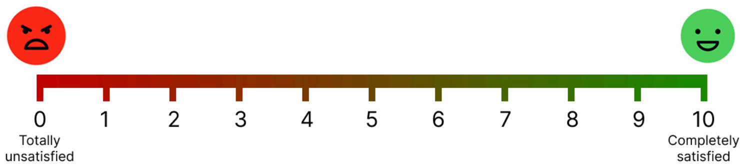


How would you improve the experience the **Oximeter** offers **when placing the equipment on patients**? Feel free to write or draw ideas and suggestions.

For the research team to fill - ID: __________

3. In person patients monitoring

Mark the level of satisfaction with the experience the **Oximeter** offered:

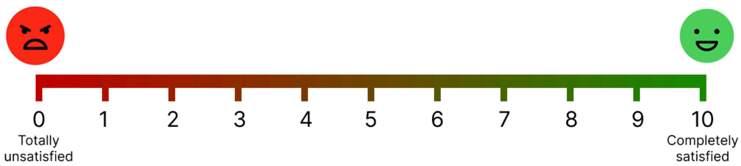


How would you improve the experience the **Oximeter** offers **when monitoring patients in person**? Feel free to write or draw ideas and suggestions.

For the research team to fill - ID: __________

4. Remote patient monitoring

Mark the level of satisfaction with the experience the **Oximeter** offered:

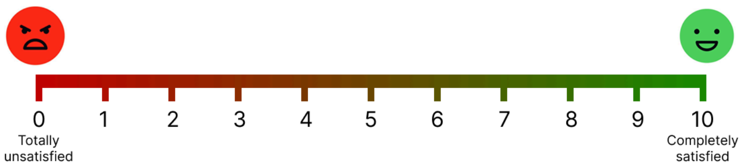


How would you improve the **Oximeter's** experience **when monitoring patients remotely**? Feel free to write or draw ideas and suggestions.

For the research team to fill - ID: __________

5. Remote patient monitoring

Mark the level of satisfaction with the experience the **Oximeter** offered:



How would you improve the **Oximeter's** experience **when withdrawing equipment from the patient**? Feel free to write or draw ideas and suggestions.

For the research team to fill - ID: __________