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Introducing a framework to translate user scenarios into engineering specifications with "action steps"

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Abstract

This study presents a three-stage framework to translate user scenarios into engineering specifications. We introduced 'Action Steps' as an intermediate tool to help convert user scenarios into functional requirements and engineering specifications. It facilitates aligning specifications with user needs by filling in the essential product information not revealed in user scenarios. Preliminary testing revealed that the proposed framework improved team understanding and reduced information gaps, showcasing its potential to enhance specification development and process efficiency.

Keywords: multi-/cross-/trans-disciplinary approaches, user-centred design, action steps, translating design information, shared understanding

1. Introduction

Today, product design and development teams thrive on multidisciplinary collaboration, blending diverse expertise to surpass traditional mono-disciplinary methods (Gericke et al., 2013). This shift towards integrating engineering with design disciplines (Borrego and Newswander, 2008) necessitates a wide array of professionals, from industrial and UX/UI designers to user research specialists and engineers. Such inclusivity and collaborative synergy (Kleinsmann, 2006) are crucial for fostering innovation derived from a deep understanding of user needs.

User scenarios in product design serve as narrative frameworks that detail user-product interactions within specific contexts, anchoring the design process in the user experience. Employed by designers, researchers, and engineers, these scenarios are pivotal throughout the ideation, validation, and development stages to ensure the final product centers on the user (Durrant et al., 2018). They serve as a critical tool for understanding user needs, contextualizing design choices, fostering a shared understanding among multidisciplinary teams, and guiding the design process, thereby enhancing the usability and relevance of the final product (Van Der Bijl-Brouwer and Dorst, 2017). Having roots in requirements engineering from software development, user scenarios are crucial for visualizing the proposed product and aiding engineers in crafting detailed engineering specifications (Cockburn, 1999; Goodwin, 2011; Kaindl, 2005; Lim and Sato, 2006; Park, 2011). 'Engineering Specifications' is defined as a comprehensive technical description of a product's requirements, synonymous with terms like specifications, design specifications, and product specifications.

Translating user scenarios into engineering specifications is essential yet complex, laying the groundwork for design requirements and guiding the development team. Inaccurate analysis of user scenarios can lead to design failures and increased costs (Brace and Cheutet, 2012). This translation approach diverges significantly from traditional engineering methods, posing challenges in integrating user research into early design phases (Ullman, 2018; Ulrich and Eppinger, 2016). Despite some attempts (Durrant et al., 2018; Lim and Sato, 2006; Park, 2011; Van Der Bijl-Brouwer and Dorst, 2017) to apply user scenarios in the different phases of design processes, there remains a notable gap in research on a formal tool that effectively translates user scenarios into actionable engineering specifications. Therefore, a novel practice integrating rich user research data with engineering principles is necessary for system-level design specification.

This paper introduces a framework designed to transform user scenarios into engineering specifications, addressing the primary challenge of translating qualitative design details into technical terms. We propose a three-stage translation process: beginning with user scenarios, proceeding through *Action Steps*, and culminating in the formulation of engineering specifications. *Action Steps* serve as crucial intermediaries, effectively bridging the gap between design insights and engineering realities. The framework aims to generate comprehensive engineering specifications that guide the product design and development team, initially focusing on these specifications before undertaking detailed refinement throughout the design process.

We conducted a preliminary test through participant observation within a multidisciplinary design project to assess our framework's effectiveness. This assessment aimed to gauge the framework's ability to accurately convert user scenarios into engineering specifications. The findings suggest that the framework is generally successful, though certain areas requiring enhancements were identified.

2. Challenges in engineering specifications development

2.1. The process of establishing engineering specifications

Establishing engineering specifications is crucial for turning a concept into reality in product design, defining functionalities and performance to meet user needs. While traditional practices enable translating these needs into product requirements (Baxter, 2018; Ullman, 2018; Ulrich and Eppinger, 2016), focusing solely on technical aspects can limit creativity and overlook user-centered design principles (Ericson, 2007; Lindmark and Nilsson, 2014). Thus, effectively bridging design and engineering through intermediate tools or methods is essential for incorporating valuable user research into the design process.

2.2. Translating design information to engineering specifications

Various tools facilitate the translation of design information into engineering specifications. However, converting qualitative user data into quantitative engineering terms remains a significant challenge. A notable gap exists between the methodologies of early-phase user research designers and later-phase engineers, highlighting a fundamental division between user-oriented and technology-oriented approaches (Figure 1).

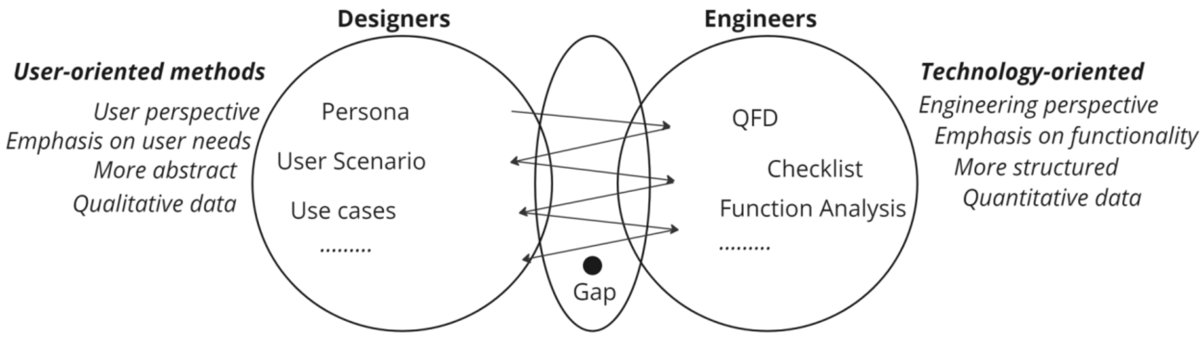

Figure 1. User-oriented vs. Technology-oriented methods

User research designers create a persona, user stories, and user scenarios to define user needs, resulting in qualitative, narrative-based design information (Cockburn, 1999; Cooper et al., 2007; Jacobson et al., 2016). This approach, which focuses on user-product interaction, often misses specific functional requirements (Kaindl, 2005) and grapples with balancing detail and abstraction (Miaskiewicz and

Kozar, 2011). Engineers need detailed, functional information for precise specifications, and the qualitative nature of user research complicates team communication. Despite the sparse focus on integrating user-oriented methods in engineering literature, merging these methods is essential for embedding user needs into product development.

Technology-oriented methods like QFD, Product Function Analysis, and Checklist prioritize quantitative measures from an engineering viewpoint, often sidelining user research outcomes. This approach leads to designs that lean more towards existing technological standards rather than incorporating user insights (Chakrabarti, 2005; Lindmark and Nilsson, 2014). In multidisciplinary projects, such a disparity can lead to communication issues between designers and engineers. Thus, there is a critical need for a new framework that effectively bridges user-oriented and technology-oriented methods, ensuring user scenarios are seamlessly converted into actionable engineering specifications.

3. Framework development

A "good" method integrates goals, procedures, rationale, framing, and mindset for internal clarity and external applicability, combining theoretical robustness with practical use (Cash et al., 2023; Daalhuizen and Cash, 2021). It ensures actionable steps, relevance, and adaptability while aligning the user's cognitive framework with the method's core for smooth application (Andreasen et al., 2015). This section outlines framework development, including elements like rationale, framing, goal, procedure, and mindset, based on Design Content Theory (Daalhuizen and Cash, 2021).

3.1. Framework elements

The *rationale* behind this research is to address the inefficiencies in product design caused by the gap between designers' user-centric views and engineers' technical perspectives, which complicates translating user scenarios into engineering specifications and causes project failure (Brace and Cheutet, 2012; Sudin and Ahmed-Kristensen, 2011). It emphasizes the need to integrate user scenarios—detailed insights into user-product interaction—into the technical design process to ensure products meet user needs.

The method is *framed* within the context of multidisciplinary teams creating highly engaging user products addressing the communication barriers between designers and engineers. It serves to develop a shared language and methodology for converting qualitative user data into quantitative, technical formats accessible to both disciplines. Achieved through a structured approach, it outlines specific *Action Steps* to streamline the translation process. The method is grounded in a brief review of current research highlighting the necessity for user-centered approaches in multidisciplinary contexts (Gericke et al., 2013; Kim and Lee, 2016; Kleinsmann, 2006; Pei et al., 2010; Pucillo et al., 2016), as well as empirical studies across various design projects. Contrary to traditional engineering design methods, which use need statements for products with lower user engagement—like mountain bike suspension systems and manual winding devices (Baxter, 2018; Ullman, 2018)—our approach is designed to convert user scenarios into engineering specifications for highly interactive products, including personal computers, smartphones, modern healthcare devices, and social assistant robots. This method emphasizes enhancing the user experience and interaction, focusing beyond technical specifications.

The primary *goal* is simplifying the transition from user scenarios to functional requirements and engineering specifications. This is achieved by dissecting user scenarios into actionable elements and mapping these to corresponding product functions, parts, technologies, and specifications.

Action Steps are introduced as a pivotal tool to streamline the design process, enhancing communication between designers and engineers, and ensuring the final product aligns closely with user expectations. By breaking down user scenarios into the minimum unit of user and product actions, *Action Steps* simplify and clarify the translation of user needs into engineering terms. This process allows for the identification of functional requirements and the necessary product parts and technologies to meet these requirements, laying the groundwork for developing precise engineering specifications. Additionally, the structural activities, their chronological and logical sequence (*procedure*), and the underlying values, principles, and logic of the method (*mindset*) are detailed in the following section, promoting a more unified and coherent approach to design.

3.2. A three-stage framework to convert user scenarios into engineering specifications

The framework comprises three stages. Designers initiate the process by deconstructing user scenarios into user actions and product counteractions, known as *Action Steps*. Once they are articulated, designers and engineers (method users) ensure a detailed, step-by-step translation from user interaction to product functionality. This framework's mindset is marked by a meticulous, user-centric approach, emphasizing precision in capturing user-product interactions and a dedication to accurately and innovatively translating these interactions into technical specifications. Once engineering specifications are defined, engineers establish target values, considering the specific context and usage within the user scenario.

3.2.1. From user scenarios into Action Steps

User scenarios are vital for maintaining a user-centric design approach, offering detailed narratives that guide from conceptualization to implementation (Lim and Sato, 2006; Park, 2011). Our framework uses these scenarios to detail explicit user actions and implicit product counteractions, enriching the understanding of user-product interactions. However, deeper insights into user needs are essential for strategic innovation (Van Der Bijl-Brouwer and Dorst, 2017). Thus, leveraging designers' creativity for defining user-product interactions ensures innovativeness in this process. Designers must ideate user and product actions by understanding user needs and defining the product function. This begins by extracting user actions from scenarios, as demonstrated when Jessica uses a smartwatch during yoga (Figure 2). Actions labeled 'Action #N' in scenarios translate into specific user interactions, with product actions inferred accordingly. Each user action paired with a product counteraction becomes an *Action Step*, laying the groundwork for further development of user and product interactions.

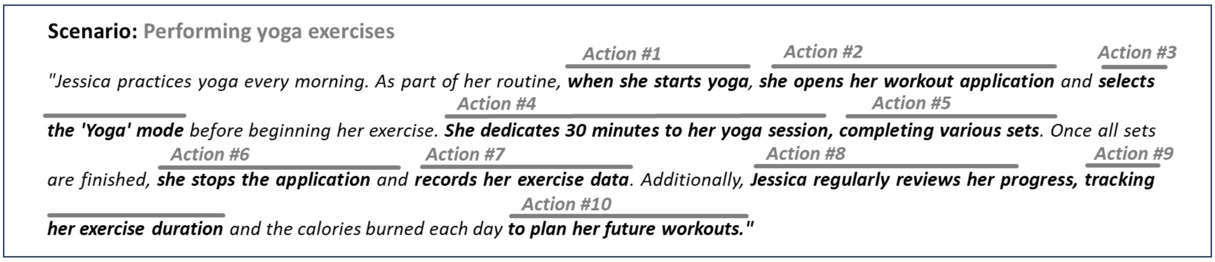

Figure 2. Example scenario of smartwatch use during exercise

Actions in user-product interactions can originate from both the user and the product, mirroring real-life engagement. For instance, in a yoga exercise scenario depicted in Figure 3, Jessica's "standing out" prompts the smartwatch to detect exercise, forming the first *Action Step*. Similarly, the smartwatch's subsequent action to start recording the exercise serves as the product's second action. These steps illustrate how user actions and product counteractions work together in defining *Action Steps*.

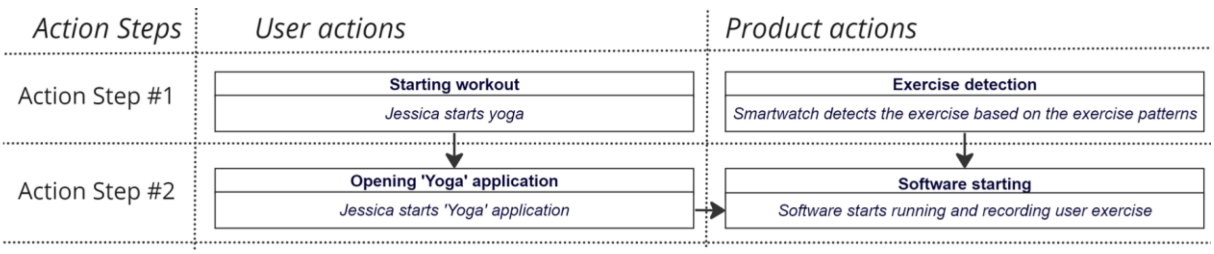

Figure 3. Example *Action Steps* extracted from a user scenario

3.2.2. *From Action Steps into functional requirements*

Describing product actions helps infer functional requirements. For example, Figure 4 illustrates "exercise detection" in a smartwatch requires recognizing and tracking exercise poses through "exercise recognition" and "data processing" functions. These functions are translated into functional requirements for the product's action. This approach allows for identifying functional requirements for each product action effectively.

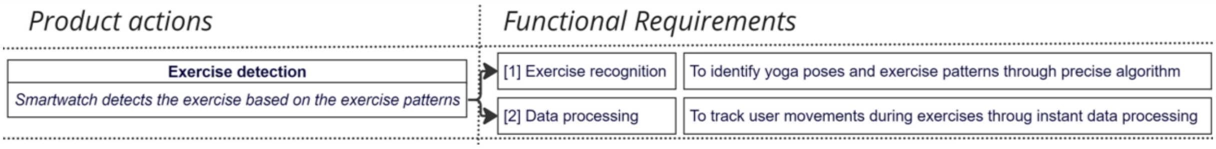

Figure 4. Example functional requirements extracted from *Action Steps*

3.2.3. *From functional requirements to engineering specifications*

The *Action Steps* framework culminates in developing engineering specifications by identifying necessary parts and technologies and formulating their specifications. Starting with a review of functional requirements from *Action Steps*, as demonstrated in Figure 5, the smartwatch's need for "exercise recognition" indicates using sensors like gyroscopes, accelerometers, rate sensors, sensor fusion, AI technology, and an exercise database. This step guides the selection of suitable sensors and technologies to meet the identified functional requirements.

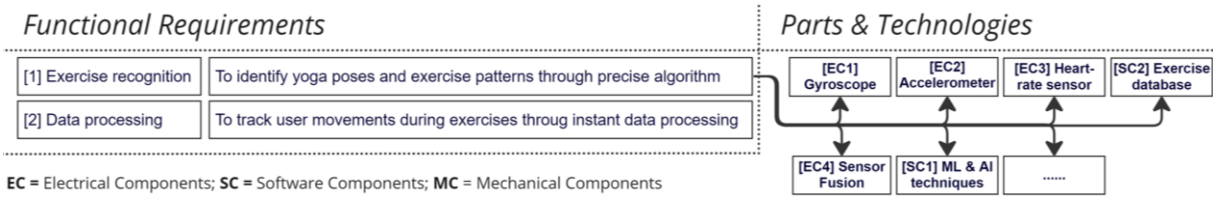

Figure 5. Parts and technologies extracted from the functional requirements

After compiling a list of parts and technologies, the engineering team, supported by designers, formulates specifications for each component. This involves evaluating each part's characteristics, its suitability for the product, and alignment with user needs. For instance, the gyroscope in Figure 5 should have an appropriate sampling rate (*at least* 10 Hz), resolution, and range (*between* ±250°/s and ±2000°/s), as well as suitable power consumption (watt) that considers the average smartwatch usage time of the user in combination with other components, which can be determined later. These criteria help in developing the "exercise recognition" feature, allowing for precise specification of each component.

4. Preliminary testing of the framework in a design project

4.1. The project context for the testing

To evaluate our framework's applicability and effectiveness, we tested it with a multidisciplinary team developing "Lemmy," a social assistant robot for older adults. The team comprised 28 experts from design and engineering fields, bringing a wide array of skills to this complex project: six User Research Designers, four Interaction Designers, five Industrial Designers, five Electrical Engineers, four Mechanical Engineers, and four Software Engineers.

User Research Designers led the development of user scenarios, while all design experts primarily focused on deriving *Action Steps* from these scenarios. Designers seek feedback from engineers on the clarity and effectiveness of *Action Steps* in specifying engineering parameters, ensuring mutual understanding and efficacy. Designers and engineers collaborated to infer functional requirements, ensuring that these requirements are comprehensive and covering both the usability aspects favored by designers and the technical aspects emphasized by engineers. This collaborative approach leverages the expertise of both professionals to enhance user experiences. Engineers led the development of engineering specifications from functional requirements, receiving continual feedback from designers to ensure these specifications align with specific user needs.

The diverse team and their sample setup allowed for an in-depth exploration of the framework across various product development stages. It provided an ideal scenario to assess the method's applicability and relevance to creating a user-engaged product and engineering specifications.

As design researchers, we crafted user scenarios and evaluated the framework using a scenario where an older adult interacts with a social assistant robot, systematically applying the framework to create engineering specifications. We utilized participant observation, grounded in ethnographic methods, to assess the framework's impact. This approach allowed for direct observation of team dynamics and the development of engineering specifications through various stages, providing valuable insights into the framework's effectiveness and its potential to drive social change and innovation in product design (Spradley, 2016).

The framework involves three key stages (Figure 6):

1. *Translation of user scenarios into Action Steps*: Initiated by designers, user scenarios were converted into *Action Steps*, serving as a bridge to convey user needs into functional requirements for engineers.
2. *Collaborative identification of functional requirements from Action Steps:* This stage involved joint discussions between engineers and designers. They scrutinized the *Action Steps* to determine the functional requirements, ensuring a comprehensive understanding of user-product interactions.
3. *Establishment of engineering specifications from functional requirements*: The functional requirements were translated into specific product components. This stage involved detailed discussions to ensure the specifications align with both user needs and technical feasibility.

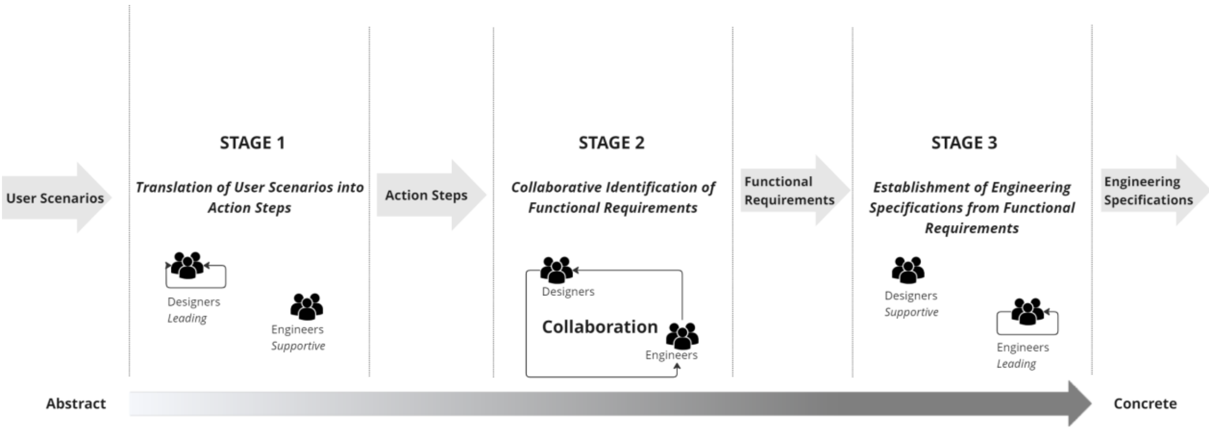

Figure 6. The procedure of applying *Action Steps* in a multidisciplinary project

The following sections present the results of this preliminary testing.

4.2. Applying the proposed framework and results

4.2.1. Initial Stage - Translating user scenario into Action Steps

In the initial development phase of the social assistant robot, an essential step was translating a user scenario into user and product actions. This process started with a specific scenario titled "Informing the weather and schedule when the user wakes up" crafted by user research designers. The scenario unfolds as follows:

> *"It is Wednesday early morning. Soonja, an elderly user, awakens in bed, pondering whether to rise. Before getting up, she wishes to know the day's weather and her schedule. She notices the robot, named 'Lemmy,' entering the room. Lemmy, offering a*

warm 'Good morning' greeting, provides her with weather updates and her daily schedule. She responds with a friendly, 'Thank you, Lemmy!'"

Scenario continues…

In this scenario, user actions like awakening are contrasted with the robot's implicit responses, such as detecting wakefulness. Equipped with the user scenario and rich research data, designers were tasked with ideating and breaking down the scenario into a series of *Action Steps*. In the ideation process, they extracted product actions by inferring based on contextual cues and user behaviors. For example, the robot's ability to detect the user's awakening might involve integrating sensors or analyzing sleeping patterns (Figure 7). This comprehensive approach was valuable for defining the robot's actions and ensuring no specific context was overlooked. Five user and five product actions — five *Action Steps* were collected and interconnected to provide rich information about user behaviors and product functions.

Action Steps were identified in brainstorming sessions using parallel actions in flowcharts to illustrate user-product interactions. This visualization clarified each interaction step, enhancing understanding of user actions and product counteractions. Categorizing actions facilitated cognitive processing (Lakoff, 2008) and improved communication among designers, promoting innovative solutions. The collaborative environment allowed for real-time input from multiple participants, improving brainstorming, iteration, and alignment on interaction flows—crucial for applying user scenarios and design thinking. Designers initially developed *Action Steps* individually, then shared and reviewed them on a shared board to represent user scenarios and structure product actions accurately. These steps were compiled and shared with engineers to collaboratively identify functional requirements, ensuring a cohesive transition from design to engineering.

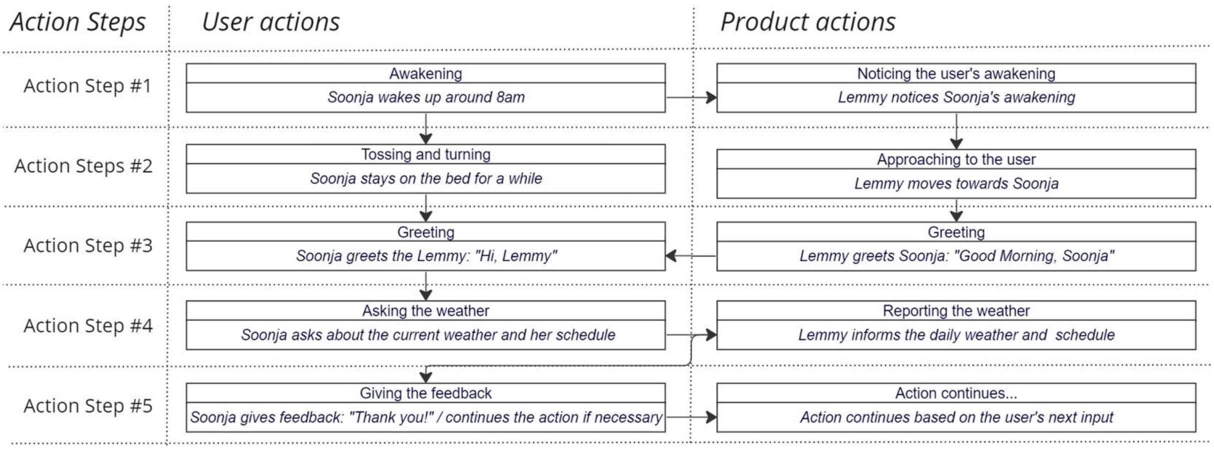

Figure 7. User scenario translation

User research, industrial, and interaction designers were crucial in extracting actions relevant to the social assistant robot, adopting the user's perspective. Engineers, though not directly involved initially, made occasional yet pivotal contributions by ensuring the technical feasibility of these actions, laying the groundwork for further development.

4.2.2. Second Stage - Functional requirements identification

In the second stage, design and engineering teams used *Action Steps* for collaborative ideation to identify functional requirements shaping the robot's features. This crucial step balanced technical feasibility with user needs. Through team meetings and analysis on a shared board, they deeply understood the intended user-product interactions and defined necessary functional requirements. This iterative process meticulously detailed the *Action Steps*, fully outlining all functional requirements (Figure 8).

The goal was to ensure the functional requirements were technically viable, desirable, and fit the product's purpose. Recurring specific requirements across user-product interactions underscored their importance for the robot's functionality.

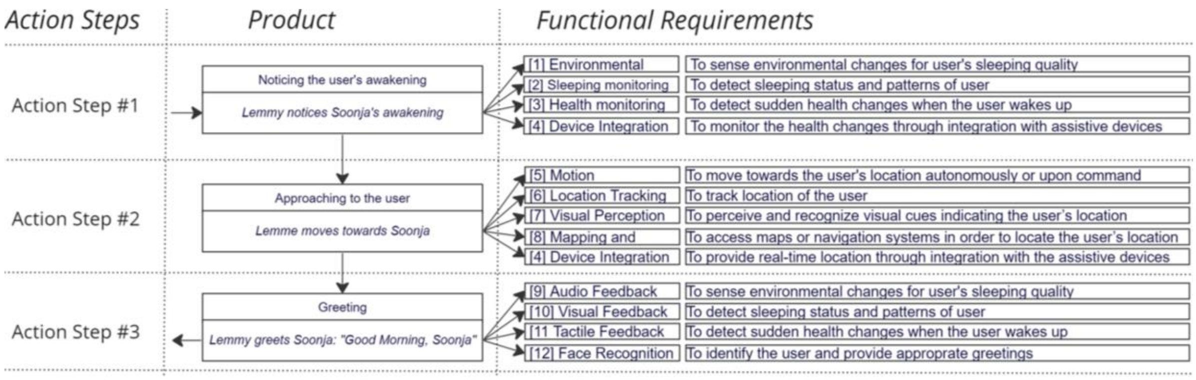

Figure 8. Extracting functional requirements from *Action Steps*

While *Action Steps* effectively identified functional requirements in collaboration with designers, engineers suggested improvements. Specifically, a software engineer highlighted the necessity of detailed data exchange between the user and the product:

> *"The specifics of data exchange and user-product interactions are not detailed, creating ambiguity in understanding technical requirements. For instance, in the weather assistant scenario, the input method (e.g., voice, touchscreen, smartwatch) for user inquiries and feedback delivery remains unspecified, complicating comprehension of the system's technical aspects." – a software engineer mentioned.*

Engineers emphasized the importance of context within each *Action Step*. They noted that without context, functions might prove ineffective across varying situations, even within the same scenario. For example, in a user waking up situation, the robot's response could be inadequate without considering factors like time, location, or specific circumstances. Clarity on these specifics is crucial to avoid inappropriate or disruptive actions by the robot:

> *"Consider the scenario where Lemmy greets Soonja upon her waking. What if Soonja wakes up at night but prefers not to be disturbed, merely wanting a drink of water? Without clarifying such context—when, where, and under what circumstances Lemmy should assist—the developed functions might disrupt rather than aid the user."- a mechanical engineer mentioned.*

4.2.3. Final Stage – Establishing engineering specifications

In this final stage, the primary task was extracting product parts and technologies, followed by establishing engineering specifications from the previously identified functional requirements (Figure 9).

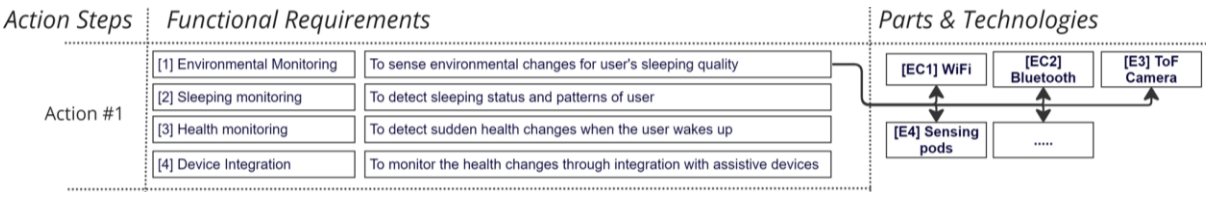

Figure 9. Identifying product parts and technologies

While engineers led this stage, they collaborated closely with designers to ensure alignment with the overall product vision. Through team discussions, mechanical, electrical, and software engineers identified critical components. Mechanical and electrical engineers focused on hardware-related features, while software engineers identified necessary software technologies.

Once a comprehensive list of necessary components was compiled, the teams embarked on establishing engineering specifications (Table 1). While engineering teams played a crucial role in this process, designers also contributed, especially when user needs were a central consideration. For instance, when determining specifications for Wi-Fi, engineers considered technical factors such as frequency bands, range, protocols, and power consumption. In contrast, designers questioned whether the Wi-Fi range suited typical room sizes in elderly homes. This approach kept engineers considering the user's context. To avoid conflicts, engineering specifications were cross-checked within and between teams. Engineers ensured that specifications did not conflict with other engineering parameters within teams. Between teams, specifications were reviewed by both designers and engineers to verify their alignment with the intended user scenarios.

Table 1. Formulating engineering specifications

#	Name	Main Functions	Type	Specifications	Target value	Units
1	[EC1] Wi-Fi	Environmental Monitoring Sleeping Monitoring Health Monitoring Device Integration	Electrical Component	1. Frequency Bands	*At least* 2.4GHz	GHz
				2. Range	*Between* 15-30 meters	meters
				3. Security	WPA2	-
				4. Power consumption	TBD	megawatt
				…..	….	….

This methodical process of translating user scenarios into concrete components exemplifies the effectiveness of the proposed framework. It guides the development from abstract user needs to identifying specific components, balancing user-centric considerations and technical feasibility.

5. Discussion

5.1. Limitations

We utilized participant observation to test our framework and assess its efficacy and effectiveness based on our observations of how designers and engineers utilize it. There could be potential observer bias and the possibility of the observer's presence altering participant behavior (Becker, 2017). Thus, careful methodological considerations are necessary to mitigate these limitations. Further research is needed to validate the method's effectiveness and efficacy using other methods suggested in the literature (Cash et al., 2023; Daalhuizen and Cash, 2021; Jan Fredrik Schønheyder et al., 2018; Matthias Eisenmann et al., 2021). Additionally, testing the framework with larger sample sizes in both design and engineering teams would enable a more in-depth exploration of its applicability across a broader range of method users.

In design field various types of user scenarios are used such as narrative textual, fictional, visual, or schematic scenarios. In this study, we utilized the narrative textual form of user scenarios. This choice raises questions about the applicability of our method when using other types of user scenarios. Therefore, further research with other types of user scenarios to test the framework is needed.

Since our framework is tailored to developing engineering specifications for products that highly engage users, its application may pose challenges for highly technical products with less user interaction. However, considering the wide range of products in different categories, testing the framework's implementation across various product designs would provide valuable insights into its effectiveness in different contexts.

5.2. Study implications

Bridging methodological gaps: The framework addresses a significant gap in the literature, where disjointed methodologies between designers and engineers often result in suboptimal product development outcomes (Kim and Lee, 2016; Sudin and Ahmed-Kristensen, 2011). The framework provides a common language by breaking down user scenarios into actionable steps, enhancing the synergy between designers and engineers. Due to their intermittent nature, traditional collaborative practices often fail to mitigate conflicts effectively. When designers send scenarios to engineers, the latter may struggle to comprehend the functions and components needed. The proposed framework, however, allows for more flexible information transitions from designers to engineers with clearly defined and gradually evolving roles throughout the stages of cooperation.

Balancing functional requirements and user needs: The proposed framework addresses a critical imbalance often seen in product design and development processes, particularly in engineering-oriented methods where functional requirements tend to overshadow user needs (Chakrabarti, 2005; Watz and Hallstedt, 2018). This imbalance has been a longstanding concern, as there is a pressing need for a clear connection between user needs and product functions (Nilsson, 2017). By integrating user scenarios into the framework to develop engineering specifications, the study responds effectively to critiques regarding neglecting user needs in the design process(Abras et al., 2004).

Enhanced collaboration and shared understanding: This framework aligns with existing studies that underscore the importance of incorporating diverse team perspectives in all stages of the specification process, thus enhancing collaboration and reducing ambiguity in product development (Ericson, 2007; Nilsson, 2017). The collaborative nature of the framework facilitated better communication and shared understanding between multidisciplinary teams. This enhancement is primarily achieved through the introduction of *Action Steps*. It serves as an essential tool for translating user scenarios into engineering language and bridging the gap between the creative, user-focused perspective of designers and the technical, function-oriented perspective of engineers. This bridging role is essential to ensure that user scenarios and corresponding functional requirements are thoroughly understood and integrated into the product development process. This collaborative approach helped address the need for integrated design practices, which is crucial for successful product development in multidisciplinary design contexts (Hubka and Eder, 2012; Kim and Lee, 2016). Simultaneously considering design intentions and technical feasibilities, the framework cultivates mutual understanding between teams. Designers gain insights into the technical aspects of product development. At the same time, engineers develop a deeper appreciation of user-centered design principles. In addition, the framework's structured approach, combining diagrams and text, resonates with human cognitive processes, making it accessible even to novice designers and engineers (Cockburn, 1999; Lakoff, 2008). This systematic approach and clarity address the common issue of vague and ambiguous guidelines prevalent in conventional methods (Röder et al., 2011).

5.3. Areas for improvement in the framework

Based on the reflections made by method users, one significant area of improvement is the need for greater detail in specifying inputs and feedback within the *Action Steps*. Engineers pointed out that the current level of detail in defining inputs and feedback is insufficient, mainly when multiple interactions occur. This lack of specificity can lead to ambiguity, compelling engineers to rely on their interpretations and available technologies, which might not fully capture user needs or foster innovation (Ericson, 2007; Lindmark and Nilsson, 2014). Addressing this, the framework has been expanded to categorize all input and output types comprehensively. Incorporating Boolean operators like AND, OR, and NOT can enhance clarity within specific contexts, guiding engineers in defining functions and selecting technologies more effectively. For example, specifying that 'The social robot reports the weather through audio AND visual information' offers clear guidance on the expected interaction modalities.

Another area for refinement is including richer contextual information within *Action Steps*. This enhancement is vital, especially when the product's response must adapt to varying circumstances. Integrating conditional feedback operators like YES, NO, IF, and THEN can significantly reduce ambiguity and ensure that *Action Steps* comprehensively cover various scenarios. For instance, specifying conditions like 'IF the user wakes up in the middle of the night and calls the robot, THEN the social robot initiates action' allows for a nuanced response tailored to specific user situations. Such detailed contextualization ensures that the product's behavior aligns accurately with the user's needs and circumstances.

To enhance detail and context, utilizing process mapping techniques instead of parallel actions in flowcharts would more effectively structure the flow and sequence of user-product activities. This approach offers method users a clearer understanding of interactions, aiding in inferring product functionality. Future research could improve *Action Steps* by integrating detailed information on actions, input types, feedback mechanisms, and conditions, effectively addressing gaps identified by engineers and yielding a more robust definition of functional requirements.

6. Conclusion

The proposed framework can potentially contribute to significantly advancing the integrated design method and process, especially in bridging the gap between design and engineering perspectives. It offers a balanced approach to incorporating both user needs and functional requirements, which is essential for the successful development of new products. However, for it to be fully effective, it needs to incorporate more detailed technical and contextual information. This approach aligns well with the current needs in multidisciplinary design practices, addressing the gaps identified in both academic and industrial contexts. The framework's potential to enhance collaboration and shared understanding by bridging design information with engineering information with *Action Steps* while being adaptable to various design challenges makes it a promising tool for future product development endeavors. Future research, including a primary test with the improved framework and expert interviews with designers and engineers from diverse industries, could further refine the framework to enhance its applicability in different design contexts and explore its effectiveness in various industry settings.

Acknowledgment

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