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User Experience Development in Elderly Heart Patient Monitoring System

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ABSTRACT — Heart disease is a major global cause of death, particularly among the elderly. Elderly often face challenges in accessing healthcare due to physical and cognitive limitations, making remote health monitoring systems a crucial solution. However, the effectiveness of these systems depends heavily on a good user experience (UX), which is often a challenge for the elderly. This research aims to develop a user-centered design (UCD) method and design a remote patient monitoring prototype that is specifically tailored to the needs of the elderly. The research employed a design science research methodology (DSRM) and included an in-depth literature review, interviews with five elderly patients and two medical professionals, a needs analysis, and the development of the FlowBeat prototype. The developed UCD method consisted of seven phases, and its validity was assessed by six UI/UX experts using the content validity ratio (CVR) and the content validity index (CVI), including item-CVI (I-CVI) and scale-CVI (S-CVI). The results showed that the research users and test the design phases were rated as the most essential (CVR = 1) and relevant (I-CVI = 1). Conversely, the creating a personal manifesto phase scored the lowest (CVR = -0.33). The overall S-CVI score was 0.93, indicating strong content validity for most of the framework. In conclusion, the creating a personal manifesto and evaluate against requirements phases performed poorly, necessitating their removal. Furthermore, further research requires testing the prototype on elderly to ensure successful implementation in the real world.

KEYWORDS — Remote Patient Monitoring, User Experience, Design Science Research Methodology, Remote Patient Monitoring Prototype, User-Centered Design.

I. INTRODUCTION

Heart disease is one of the leading causes of death worldwide, including in Indonesia. Data shows that heart disease sufferers in Indonesia are predominantly elderly, with a total of 4,745 people [1]. An analysis of more than 193 million respondents has also shown that the elderly group has the highest risk, at 65.8% [2]. The prevalence of heart failure also increases with age, from 6% in those aged 60–79 years to 14% in those aged 80 years and above [3]. These data emphasize the importance of comprehensive treatment and ongoing health monitoring in elderly patients to detect changes in their condition early and prevent fatal complications [4].

Remote heart health monitoring technology is a relevant solution, enabling early detection without having to wait for a physical examination at a health facility [5]. However, the effectiveness of these systems depends not only on the sensor technology but also on the user experience (UX), especially for elderly users who often have limitations in using modern technology [6], [7]. Poor UX can make it difficult to use, reduce the effectiveness of monitoring, and risk diminishing health benefits [8], [9].

Developing systems for Indonesian elderly faces unique challenges, such as a lack of technological experience (most elderly is digital immigrants), as well as various physical and cognitive limitations (vision, hearing, and memory), which require simple interface design, good color contrast, and clear navigation [10]–[13]. Trust and perceived ease of use also significantly influence technology adoption by elderly [9], [14]. Despite these challenges, the trend of technology adoption among Indonesian elderly shows a positive growth. A 2024 statistical report showed that nearly half of the elderly population (49.27%) already used a mobile phone, and internet access had doubled to 26.42% compared to 2020 [15]. This trend opens significant potential for implementing digital health systems. However, maximizing this potential requires a user-centered design (UCD) approach that specifically addresses the unique challenges faced by elderly.

The UCD process often faces obstacles, such as differing perceptions between designers and elderly, as well as highly diverse needs [16]. This gap is evident in the results of the system usability scale (SUS) test on the existing system, which only achieved a score of 48.3—far below the minimum accepted score (≥ 70) [17]. Therefore, the development of a more inclusive UCD approach is needed to improve the user experience of elderly people in health monitoring systems.

This study offers novelty by developing an adaptive UCD method tailored to the needs of elderly in Indonesia, systematically integrating input from users (elderly) and medical personnel [18]. The main contributions of this study are the development of a more adaptive UCD framework for elderly users in Indonesia, and the development of a prototype internet of things (IoT)-based heart health monitoring system using Max30100 and Polar H10 sensors to monitor SpO2 and heart rate in real time [19], [20].

IoT technology was first introduced in 1999 [21], with a concept that allows various intelligent objects to be connected and interact with each other, both with other devices, the surrounding environment, and other computing systems via the internet network [21], [22]. Along with the development of technology, IoT has begun to be applied in the remote patient monitoring system [23], utilizing wearable devices, sensor networks, and digital infrastructure to answer the challenges of conventional health systems while improving the quality of life of patients and health services as a whole [23].

This system is expected to improve the quality of remote patient monitoring for elderly and provide accurate information to medical personnel for rapid decision-making. Socially, this research has the potential to improve the quality of life for elderly by enabling them to independently monitor their heart condition, reducing dependency, and providing a sense of security.

II. METHODOLOGY

This research uses the DSRM approach to develop a cardiac monitoring system for the elderly. Figure 1 illustrate the research flow using the design science research methodology (DSRM) approach [24], [25]. DSRM is a research method that combines design principles and research methodologies to develop and evaluate innovative solutions to complex problems [26]. Table I illustrates the implementation of each phase of the DSRM, starting with the identify problem & motivate phase. It was identified that the elderly, as a vulnerable group for heart disease, have difficulty using IoT-based health monitoring systems due to physical and cognitive limitations, and less user-friendly interface designs, as evidenced by low system usability scale (SUS) results. The define objectives of a solution phase sets the goal of developing a UCD method that focuses on the needs of the elderly to design an intuitive and easy-to-use remote monitoring system interface, thereby improving comfort, effectiveness of use, and quality of life for heart disease sufferers. The design & development phase contains the development of the UCD method, which is then continued in the demonstration phase by implementing the method in the development of an elderly monitoring system called FlowBeat. In the evaluation phase, expert testing is conducted to assess the effectiveness of the developed UCD method. Finally, in the communication phase, the research results are published in the form of a scientific article in a Sinta 2 indexed journal.

This research stems from the need to develop an adaptive UCD method, given that standard UCD methods, as outlined in ISO 9241-210 [27] and other frameworks [28]–[30], lack specificity in addressing the challenges of elderly users. Based on a literature review of these various approaches, this study proposes a new UCD model integrating core stages, such as understanding the user context, identifying needs, designing solutions, and evaluating the design, with a particular emphasis on actively engaging elderly and healthcare professionals from the outset.

The proposed UCD method was validated by experts using the content validity index (CVI) and content validity ratio (CVR). CVI is a measure used to assess the relevance and representation of items in an instrument based on expert assessments. A high CVI value indicates that the item is considered relevant by the majority of experts [31], [32]. CVI consists of two main types: item-CVI (I-CVI) and scale-CVI (S-CVI). I-CVI is a measure of content validity at the individual item level [33].

Equation (1) defines the I-CVI. I-CVI is calculated by dividing the number of experts who rated an item as relevant (usually with a score of 3 or 4 on the Likert scale) by the total number of experts who rated it [34]. For a panel of six experts, the minimum accepted value for the I-CVI is 0.78 [35].

$$\text{I-CVI} = \frac{Number\ of\ experts\ who\ gave\ a\ rating\ of\ 3\ or\ 4}{Total\ experts} \quad (1)$$

Equation (2) defines the S-CVI. S-CVI is a measure of content validity at the overall scale level. S-CVI can be calculated based on the average I-CVI value of all items [36], [37]. $\Sigma\, I - CVI$ denotes to the content validity index for each item. The minimum value accepted for S-CVI is 0.8 for 6-10 experts [38].

$$\text{S-CVI} = \frac{\Sigma\ \text{I-CVI}}{Total\ item} \quad (2)$$

Equation (3) defines the CVR. CVR involves the assessment of a panel of experts who rate each item as essential, useful but not essential, or unnecessary [39]. CVR is calculated to determine which items should be retained or removed [39]. In some studies, CVR is used to determine whether an item should be retained or removed from an instrument [31]. The minimum CVR value that is often used is 0.62 [40]. n_e is the number of experts who rate the item as essential, while N is the total number of experts who assessed.

$$\text{CVR} = \frac{n_e - \frac{N}{2}}{\frac{N}{2}}. \quad (3)$$

After the UCD method was validated, the next stage was to create a prototype of a remote monitoring system for the elderly to visualize the initial system design. This prototype was developed iteratively based on the needs analysis from the interview phase and user suggestions.

III. RESULTS AND DISCUSSION

This study presents the results of the development of a UCD method focused on the elderly and its implementation in the design of a prototype heart health monitoring system, FlowBeat. This section outlines the stages of the method development, the results of its validation by experts, and a critical discussion of the findings.

A. IDENTIFYING USER NEEDS

This phase aims to deeply understand user needs, behaviors, and motivations. Interviews were conducted with five primary users of the system, elderly people aged 61–74 years with heart disease, to understand their needs for a remote health monitoring system. In addition, interviews were conducted with two physicians, namely an internal medicine specialist and a cardiology specialist, to validate the system's requirements. A summary of the identified needs is presented in Table II.

The interview results indicated that the elderly's needs focused on ease of use and essential features, such as a mobile-based system that can detect oximeters and pulse rates, display data simply (graphs and numbers), provide notifications, and have an emergency call feature. Meanwhile, physicians recommended a more comprehensive system to support medical decisions. It was recommended that the system must be able to detect pulse rate and SpO2, record patient medical history in real time, provide emergency notifications, restrict data access rights, and allow the system to make emergency calls to patients. The results of these interviews served as the primary basis for the system design phase.

B. IMPLEMENTATION OF THE DEVELOPED UCD METHOD

Based on a literature review, a UCD method was developed with reference to the ISO 9241-210 standard and related literature [28]–[30]. This method consisted of seven phases. The diagram in Figure 2 shows the structured steps in this method.

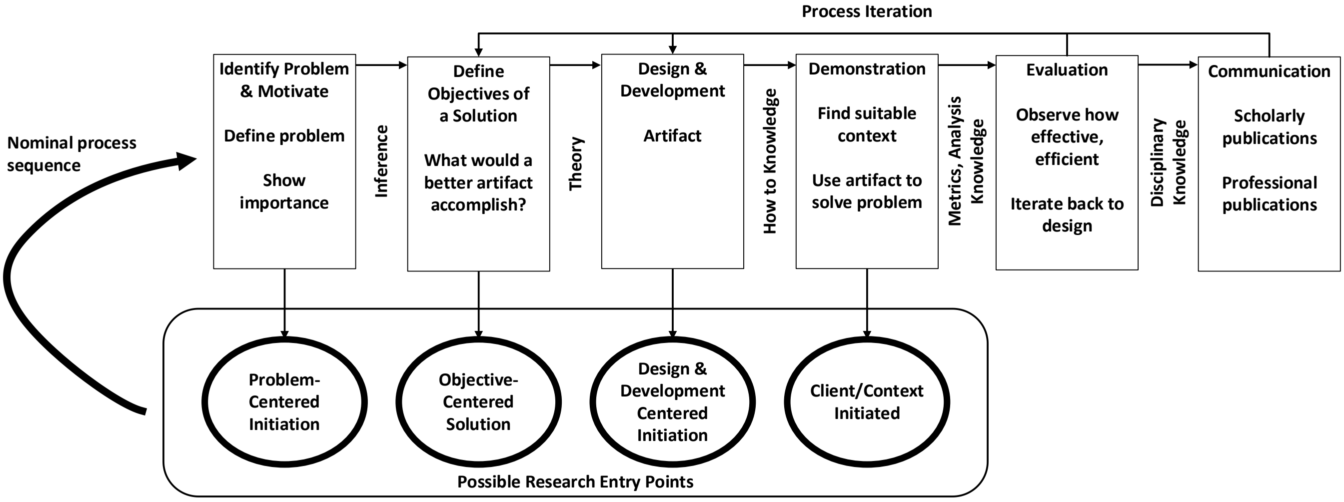

Figure 1. Design of science research methodology (DSRM).

TABLE I
THE RELATIONSHIP BETWEEN DSRM AND RESEARCH IMPLEMENTATION

DSRM Phase	Research
Identify problem & motivate	Elderly, who are vulnerable to heart disease, struggle to use IoT-based health monitoring systems due to physical and cognitive limitations and poor interface design, leading to low usability as shown by substandard SUS scores.
Define objectives of a solution	Developing a UCD method that focuses on the needs of the elderly to design an intuitive and easy-to-use remote monitoring system interface, thereby improving comfort, effectiveness of use, and quality of life for the elderly with heart disease.
Design & development	Developing the UCD method.
demonstration	Implementing the development of an elderly monitoring system (FlowBeat) using the developed UCD method.
Evaluation	Expert testing was conducted to test the UCD method that has been developed.
Communication	The research results are published in the writing of journal articles indexed by Sinta 2.

TABLE II
RESPONDENT INTERVIEW RESULTS

Respondents	Needs
Elderly	• Mobile based system. The system can detect the oximeter and pulse, display monitoring results using graphs and numbers, provide notifications and suggestions based on heart rate conditions, contact the emergency center through the system
Doctor	The system can detect pulse rate and SpO2, record the patient's heartbeat and can be accessed at any time, provide notifications to direct patients to the emergency room if the patient's condition is an emergency, provide access rights so that not all doctors can access patient data, has a feature for patients to contact an emergency call center.

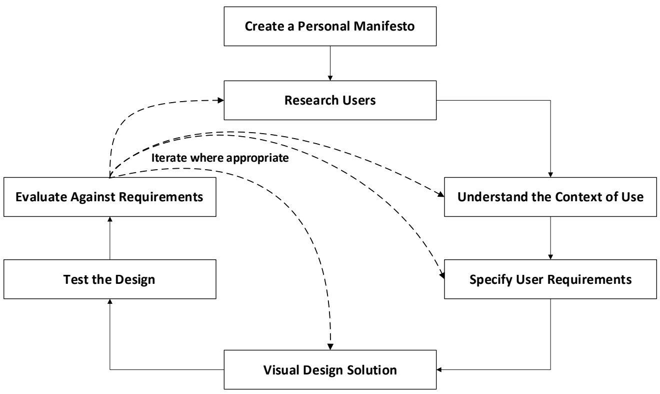

Figure 2. UCD method that has been developed.

The UCD method developed in this study consisted of seven phases that systematically guide the design process, with the FlowBeat prototype as the concrete result of its implementation. The creating a personal manifesto phase served as a philosophical foundation that formulated the project vision as a starting point to achieve the primary goal of creating a heart health monitoring system for the elderly that was easily accessible, safe, reliable, and responsive to emergencies, while ensuring data privacy and providing medical recommendations. The user research phase yielded an in-depth understanding of the needs of the elderly, as summarized in Table II. Furthermore, the understanding the context of use phase analyzes the use of FlowBeat in various everyday scenarios. FlowBeat must provide easily accessible real-time monitoring for the elderly at home or in environments with limited healthcare access, and it should also provide emergency notifications to families to enhance their sense of security. In the specify user requirements phase, the requirements obtained from interviews were refined into technical specifications using a triangulation approach to ensure each feature was essential, relevant, and aligned with the system's business objectives.

In the visual design solution phase, a prototype based on elderly-friendly design principles was developed. These include a simple interface with large, clear buttons; intuitive navigation based on simple gestures (such as tapping) while avoiding complex gestures (such as swiping and zooming) that might be challenging for elderly [41]; the use of a 16–22 pt Sans Serif font (Poppins) with high contrast to address visual impairment [42], [43]; and safety features such as a clear back button and easily accessible emergency calls [44].

Figure 3 exhibits the home page of the elderly heart monitoring system application called FlowBeat. The home

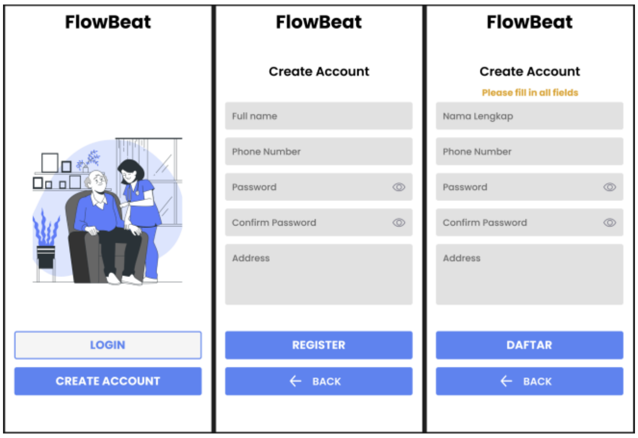

Figure 3. Prototype of the home page and account registration.

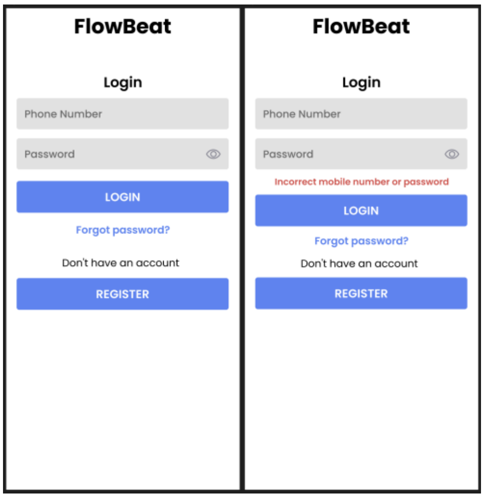

Figure 4. Account login prototype.

page contains buttons to log in (Login) and create an account (Register) for users who do not have an account. On the create account page, users were asked for personal data and account passwords to maintain data security.

Figure 4 shows the FlowBeat login page. Users entered their mobile phone number and password used on the registration/create account page. This page also included a forgot password feature and a create account button, making it easier for users to recover access if they forgot their passwords or to register if they had not yet created an account.

Figure 5 exhibits the features of the Flowbeat home page. This page displayed the user's heart rate, and SpO2/body oxygen in a concise manner, the emergency call feature, the user's photo and name, and the notification feature. The system displayed the heart rate and SpO2 details after the user pressed the "Heart Rate" and "Body Oxygen" display.

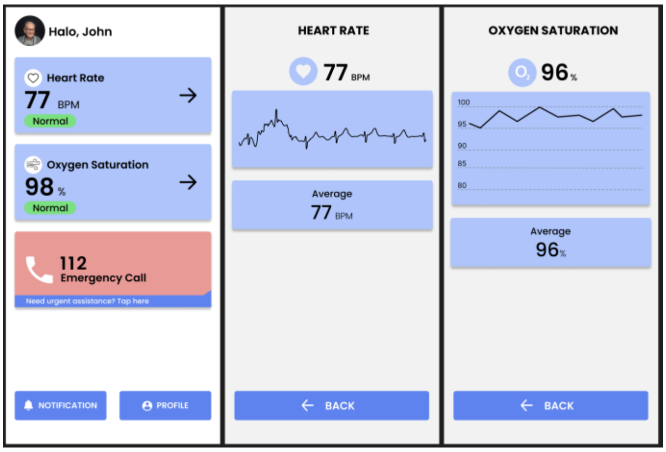

Figure 5. Prototype of the main page heart rate and SpO2 details.

The system's display changes if the user's vital condition is abnormal, as in Figure 6. The system provided first aid advice for the user. This feature was designed to display a pop-up with a dark background to create high contrast so that the elderly could focus on the feature and made it easier for them to read the notification [42]. Meanwhile, if users need help, they could press the "Emergency Call" feature to contact the emergency call center.

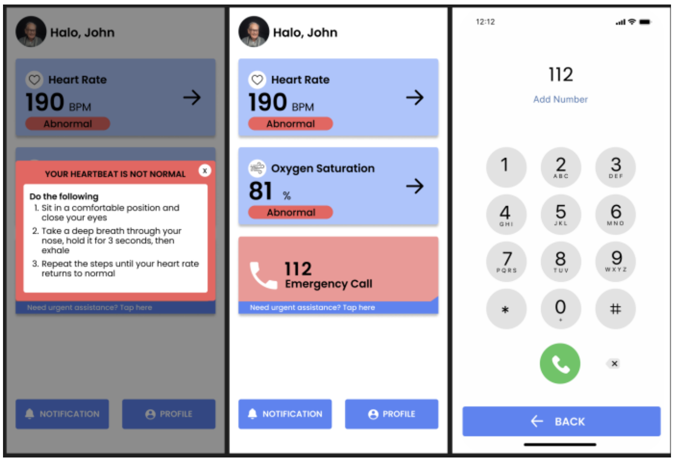

Figure 6. Prototype display when the patient's vital conditions are outside the normal range.

Figure 7 presents the notification and user profile features. The system saved the history of abnormal user vital conditions in the "Notification" feature. This feature also provided action solutions to restore the user's condition. Then, on the account page, the user could update the profile and log out of the account. In the test the design phase, a testing was conducted with end users to identify usability issues planned for future research. Finally, the evaluate against requirements phase focused on evaluating the prototype's suitability to user needs.

C. EXPERT VALIDATION OF THE UCD METHOD

A validation test was conducted with six UX experts to assess the essentiality and relevance of the seven proposed UCD phases. The experts had over five years of experience in UI/UX design and UX research. They were also asked to rate each phase of the UCD method based on its essentiality (CVR) and relevance (I-CVI). It should be noted that there were seven main phases tested, and each phase was assessed based on two aspects: essentiality and relevance. Therefore, a total of 14 questions (Table III) were asked for each of the seven phases.

Table III lists questions used to assess whether the design stage is essential and relevant. Hence, in the assessment scale, a distinction was made between the assessment scale of essential and relevant questions. Questions related to the essentiality of a design stage were assessed on a scale of not needed (1), useful but not essential (2), and very essential (3). Meanwhile, questions related to the relevance of a design stage were assessed on a scale of not relevant (1), less relevant (2), relevant (3), and very relevant (4).

Based on Table IV, the most essential phases according to experts are research users and test the design, with a CVR value of 1, indicating that all experts considered this phase to be very

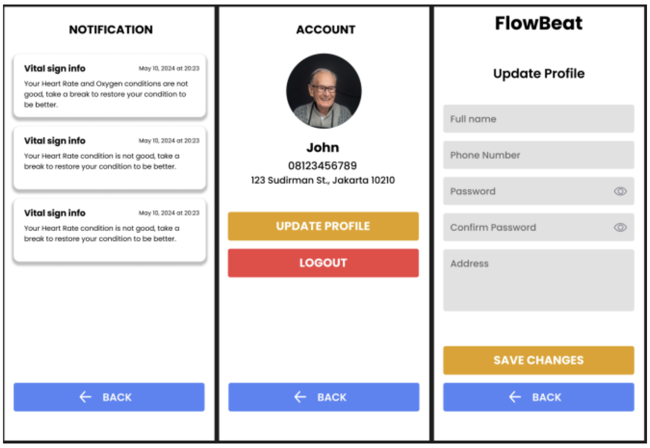

Figure 7. Prototype of notification, account, and profile update features.

TABLE III
EXPERT TEST QUESTIONS

No.	A List of Questions
1	Is the 'Creating a Personal Manifesto' element essential to this UCD method?
2	Is the 'Creating a Personal Manifesto' stage relevant to the UCD process?
3	Is the 'Research Users' element essential for this UCD method?
4	Is the 'User Research' stage relevant to the UCD process?
5	Is the element of 'Understanding the Context of Use' essential for this UCD method?
6	Is the 'Understanding Context of Use' stage relevant to the UCD process?
7	Is the 'Define User Requirements' element essential for this UCD method?
8	Is the 'Define User Requirements' stage relevant to the UCD process?
9	Is the 'Visual Design Solution' element essential for this UCD method?
10	Is the 'Visual Design Solution' stage relevant to the UCD process?
11	Is the 'Design Test' element essential for this UCD method?
12	Is the 'Design Test' stage relevant to the UCD process?
13	Is the 'Evaluation Against Requirements' element essential for this UCD method?
14	Is the 'Evaluation Against Requirements' stage relevant in the UCD process?

TABLE IV
ESSENTIAL TEST RESULTS

Phase	Expert						CVR
	1	*2*	*3*	*4*	*5*	*6*	
Creating a personal manifesto	3	3	2	1	2	2	-0.33
Research users	3	3	3	3	3	3	1
Understand the context of use	2	3	2	3	3	3	0.33
Specify user requirements	3	3	3	2	3	3	0.67
Visual design solution	2	3	3	3	3	3	0.67
Test the design	3	3	3	3	3	3	1
Evaluate against requirements	3	3	3	1	2	3	0.33

TABLE V
RELEVANCE TEST RESULTS

Phase	Expert						I-CVI
	1	*2*	*3*	*4*	*5*	*6*	
Creating a personal manifesto	3	4	3	1	3	3	0.83
Research users	4	4	4	4	4	4	1
Understand the context of use	3	4	3	4	3	4	1
Specify user requirements	3	4	4	3	4	4	1
Visual design solution	3	4	4	4	4	4	1
Test the design	4	4	4	4	3	4	1
Evaluate against requirements	4	4	4	1	2	4	0.67
S-CVI = (0.83 + 1.00 + 1.00 + 1.00 + 1.00 + 1.00 + 0.67) / 7							0.93

important in the UCD-based development process. The specify user requirements and visual design solution phases obtained a CVR of 0.67, meaning that these two phases were considered quite essential in this study, although there were still some differences of opinion among experts. Meanwhile, the understand the context of use and evaluate against requirements phases had a CVR of 0.33, indicating that although these phases were considered relevant, some experts did not fully assess both as very essential aspects in design. The phase with the lowest CVR value is creating a personal manifesto (-0.33), meaning that most experts did not consider it an essential part of this study. Negative values indicate that this phase may have less strong relevance in the context of the study and needs to be reconsidered in system development.

Based on Table V, the most relevant phases according to expert assessments are research users, understand the context of use, specify user requirements, visual design solution, and test the design, each with an I-CVI score of 1.00. These results indicated unanimous agreement among experts regarding the high importance of these phases in a UCD approach. In contrast, the phases of evaluating against requirements and creating a personal manifesto received lower I-CVI scores of 0.67 and 0.83, respectively, suggesting some degree of disagreement among experts regarding their relevance. Notably, one expert rated evaluate against requirements as not relevant (score = 1), highlighting the need for further review and potential refinement of this phase to enhance its applicability in the developed system. The overall S-CVI obtained was 0.93, exceeding the commonly accepted threshold of 0.80, indicating that most phases in the proposed UCD framework were considered highly relevant by the panel of experts. Nevertheless, phases with I-CVI scored below 0.78—specifically creating a personal manifesto and evaluate against requirements—should be reevaluated to ensure their meaningful contribution and alignment with user needs in the final implementation.

Validation by UX experts, in addition to confirming the overall robustness of the proposed UCD method (S-CVI of

0.93), also provided critical feedback on specific phases. The low CVR for creating a personal manifesto and the low I-CVI for evaluating against requirements indicated that these phases were not considered essential or relevant in this specific context. Therefore, these phases should be considered for removal to create a leaner and more focused framework. This demonstrates a commitment to refining the method based on empirical feedback, a hallmark of robust scientific research. The UCD method developed in this study was adapted from ISO 9241-210 and several studies [28]–[30]. In terms of practical contribution, the FlowBeat prototype was designed as a response to the limited adoption and low user satisfaction of elderly patients with existing remote patient monitoring systems. Previous studies have highlighted common shortcomings, such as the lack of consideration for the elderly's ability to independently navigate complex systems [45], and the neglect of physical limitations that affect interaction [8]. By addressing these gaps, FlowBeat introduces an elderly-friendly design that emphasizes simplicity, clarity, and accessibility, thus offering a more viable alternative to existing RPM solutions.

IV. CONCLUSION

This study has successfully developed and validated a UCD method tailored for the development of a heart health monitoring system for the Indonesian elderly. The UCD method, consisting of seven key phases (creating a personal manifesto, researching users, understanding the context of use, specify user requirements, visual design solutions, test the design, and evaluate against requirements), was evaluated for its essentiality and relevance by six UI/UX experts. The validation results confirmed the importance of several phases, particularly research users and test the design, which both received a CVR and I-CVI score of 1, indicating unanimous expert agreement on their high importance. This highlights the criticality of direct user engagement and design testing in creating an effective system for this user group. However, the validation also provided critical feedback on phases that require further attention. The creating a personal manifesto phase was rated as the least essential, with a CVR of -0.33, while the evaluat against requirements phase received a lower I-CVI score (0.67). These findings suggest that these phases may need to be removed to create a more efficient and focused framework. The overall method demonstrated high validity, with a S-CVI of 0.93, surpassing the accepted threshold of 0.80. The practical implementation of this method resulted in the FlowBeat prototype, which was designed with inclusive principles such as large fonts (16–22 points), high contrast, and tap-based navigation to meet the specific needs of elderly users. The study recommends that future research should focus on the real-world implementation of the prototype and on refining the suboptimal phases to ensure the system's long-term desirability and effectiveness.

CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHORS' CONTRIBUTIONS

Conceptualization, Tien Fabrianti Kusumasari and Sinung Suakanto; methodology, Muhamad Ivan Fadilah and Alaric Rasendriya Aniko; software development, Muhamad Ivan Fadilah, Alaric Rasendriya Aniko; method validation, Alaric Rasendriya Aniko; formal analysis, Muhamad Ivan Fadilah and Alaric Rasendriya Aniko; identification of user needs, Alaric Rasendriya Aniko; data accuracy, Muhamad Ivan Fadilah; writing—original draft, Alaric Rasendriya Aniko; writing—review and editing, Tien Fabrianti Kusumasari; prototype visualization, Alaric Rasendriya Aniko; supervision, Tien Fabrianti Kusumasari; project administration, Tien Fabrianti Kusumasari; funding acquisition, Tien Fabrianti Kusumasari.

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