The Development of Patient Monitoring System Application: Integrating Design Thinking and QFD Method

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Keywords	ABSTRACT
Patient monitoring system, Design Thinking, Quality Function Deployment	COVID 19 and other diseases with high risk of transmission lead to hospital occupancy restrictions. On the other hand, the patient's family needs to know the most recent patient condition. This research aims to design a patient monitoring system. Thus, the patient's family can monitor the patient's condition without visiting the hospital to reduce the transmission risk. The process of designing this monitoring system is carried out using a design thinking approach which consists of an empathy process, define, ideate, prototype, and test. This design thinking approach is combined with the Quality Function Deployment method. This approach was chosen because design thinking can solve problems effectively by understanding user needs and redefining the user experience problems. The result of this research is the patient monitoring system mockup. The mockup usability was tested using usability questionnaire. Respondents who are stakeholders in one of the hospitals agree that the developed patient monitoring system could solve existing problems.

INTRODUCTION

Various kinds of diseases are experienced by patients, ranging from mild illnesses, moderate illnesses, and severe illnesses, these diseases are classified based on clinical studies, for example colds caused by viral infections in the respiratory tract that do not have the potential to cause severe complications to diseases that have severe symptoms and can cause severe complications such as strokes and heart attacks (Irna, 2019). In addition, patient handling and treatment in hospitals also varies, some are executed with one appointment or outpatient, some must be hospitalized. One hospital in Central Java has a rule that only one person can accompany a patient, but for certain disease conditions, more than one person is allowed to be treated. The occupancy restriction on the number of visitors must be obeyed by family members of patients. Thus, there are difficulties experienced by families to monitor the patient's condition.

Hospital occupancy restrictions are implemented due to the high risk of transmission of diseases such as COVID-19. Transmission of COVID-19 occurs through aerosols, droplets, and direct contact with patients (Tellier, Li, Cowling, & Tang, 2019). Transmission of COVID-19 in the air in the sense of direct contact is one of the highest transmissions of COVID based on reports of SARS incidents in the past (Sheng, RN, RN, & RN, 2020). This is supported by the burden of infection of health workers and the risk burden experienced by health workers. Health workers contribute a significant proportion of COVID-19

infections because they are in an environment with a high risk of infection and direct contact with patients (Chou, et al., 2020). According to the International Council of Nurses (2021), more than 1.6 million healthcare workers have been infected in more than 34 countries, with an average of about 10% of all confirmed COVID-19 infections occurring among healthcare workers, with a range of 0-15%. At the time of the data review, more than 90 million people had been infected with COVID-19, resulting in 1.9 million deaths worldwide. Risks can also occur to families of patients who want to observe or monitor their family's condition in the hospital (ICN, 2021). Therefore, it is necessary to have an applicationbased information system that can be accessed by family members. This research aim to develop an internet-based information system that can be accessed from their respective homes to be able to monitor the patient's condition at any time will increase the effectiveness of disseminating information about the patient's condition in the hospital. The application database will be continuously updated by the nurses who maintain it, thus minimizing family members' worries about the patient.

One of the models or concepts designed to conduct new product design (NPD) is design thinking. Design thinking can be broadly described as a creative problem-solving approach using the designer's perspective including associated principles, mindsets, methods, and tools (Brown, 2009). In the managerial realm, Design thinking is often described as a human-centered problem-solving approach that emphasizes observation, collaboration, rapid learning, visualization of ideas, rapid prototyping of concepts, dealing with complexity and ill-defined problems.

In addition to design thinking, there is a more traditional product development approach that is oriented towards a concept generation perspective influenced by user preferences, namely Quality Function Deployment (QFD). The QFD method is used to design new products and services and modify existing products and services so that they can meet the needs specified by customers. This method belongs to the customer-oriented method, which means that design does not start the work of planning product characteristics, but customer requirements and then designing products or services to meet these requirements or needs. In general, QFD is translating customer requirements to appropriate company actions in all phases of product quality development.

In this study, the method used to design patient monitoring system application is the integration of design thinking and Quality Function Deployment. As far as our knowledge, there are few research use the combination of design thinking and Quality Function Deployment and there is no previous research using this integration methods to develop the patient monitoring system application. The integration of the two product development methods is intended to produce products that meet user needs.

METHODS

Design thinking can be described as a human-centered problem-solving approach that emphasizes observation, collaboration, rapid learning, visualization of ideas, rapid prototyping of concepts, dealing with complexity and ill-defined problems. According to Liedtka (2014) design thinking generally consists of three stages: data collection about user needs, idea generation, and testing (Liedtka, 2014). This corresponds to what Seidel & Fixson (2013) refer to as "needs-finding, brainstorming, and prototyping". It should be noted that although there are different phases that are distinct, the fundamental nature of design thinking is an iterative approach. User-generated products are mostly a direct result of users' unmet needs based on their personal experiences. Therefore, products developed based on users' own experiences incorporate deep user understanding and may even be relevant for other users with similar needs (Jong, Hippel, Gault, Kuusisto, & Raasch, 2015).

This approach was chosen because design thinking is a process that helps developers in designing products based on a human-centered approach (user). However, many studies are related to design thinking through five processes, such as empathize, define, ideate, prototype, and testing. At the prototype stage, it is combined with the Quality Function Deployment method to simplify the design of mockups in the application.

Quality Function Deployment (QFD) is a product development method that is described as a transparent process, meaning that every process in product development is carried out from understanding user needs to establishing quality planning and determining product design quality. The quality of the designed product is composed of several elements, including product functionality, components or features in the product, product manufacturing or development process, and several

other elements. Quality Function Deployment can be used as a tool that can help us gain control over the quality set by the user.

According to Meinel et al (2018), the use of the design thinking approach in the Quality Function Deployment method has a significant positive effect on the feasibility of the product concept, the relevance of the product concept to user needs, and the specificity of the concept. This means that by incorporating design thinking principles into the Quality Function Deployment (QFD) process, the product design process can pay more attention to user needs and create more feasible and specific product concepts. Design thinking emphasizes a human-centered approach to solving problems, resulting in a deeper understanding of user needs and wants. By using this approach in the QFD process, the product design process can be more comprehensive about user needs and preferences, leading to the creation of products that are more relevant and attractive to customers. In addition, the specificity of the product concept also increases, as design thinking encourages thinking about every detail of the product and its user experience. Ultimately, the use of design thinking in the QFD process can lead to the development of higher quality products that better meet user needs and preferences.

In this method, problems that occur in product development are approached from the point of view of "what is needed by customers". The implementation of Quality Function Deployment aims to identify the critical points of a wide quality network, improvements can be made easily can be made easily. Thus, the purpose of this model is to provide a structured standard of learning implementation. Data collection is carried out at the prototype stage of design thinking, in this study data collection was carried out using a questionnaire with the aim of identifying the advantages and disadvantages of the patient monitoring system initial mockup that had been made at the previous stage (ideate stage).

The following are the questions from the questionnaire:
1. Do you think there are any features that need to be added?
2. Do you think there is any other information that the patient's family needs to know?

The population in this study were all employees of one of the hospital houses in Central Java, with a total sample in this study of 41 people consisting of Relationship Managers, doctors, executive nurses, emergency room nurses, and executives. The hospital employees were chosen as respondents because they know more about the details related to communication between the hospital, patients, and patients' families.

The integration between design thinking and Quality Function Deployment is illustrated in a conceptual model, which is a diagram that represents several relationships between certain factors that influence or lead to a target outcome. The design methodology was designed by taking a design thinking approach. The conceptual model can be seen in the figure below.
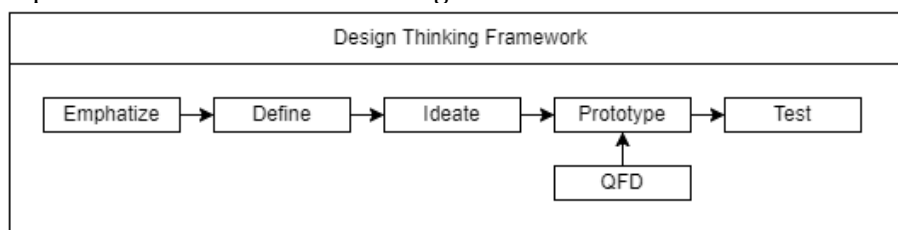

Figure 1 Integration Model

RESULTS

First Mockup

The research starts by empathizing on the real situation that occurs. The empathy stage means that observations are made with the aim of digging up information so as to define the problem from the user's point of view. The problem that arose at that time was the lag of information between patients at the hospital and the patient's family at home. The impact of the lag of information is the concern of the patient's family at home so that it has an impact on activities and productivity. In addition, information constraints also cause confusion on the part of the patient's family regarding the actions they must take in relation to the patient. After conducting the empathy process, the process continued with the define stage.

This stage is the stage where an analysis of predetermined problems is carried out, so a solution is formulated in the form of a monitoring system for the patient's condition through the application as a medium for transferring information from the hospital to the patient's family and from the patient's family to the hospital. Afteward, process continued with the define stage, which is the stage of designing a mockup based on the steps that have been done before. The mockup can be seen in the image below.
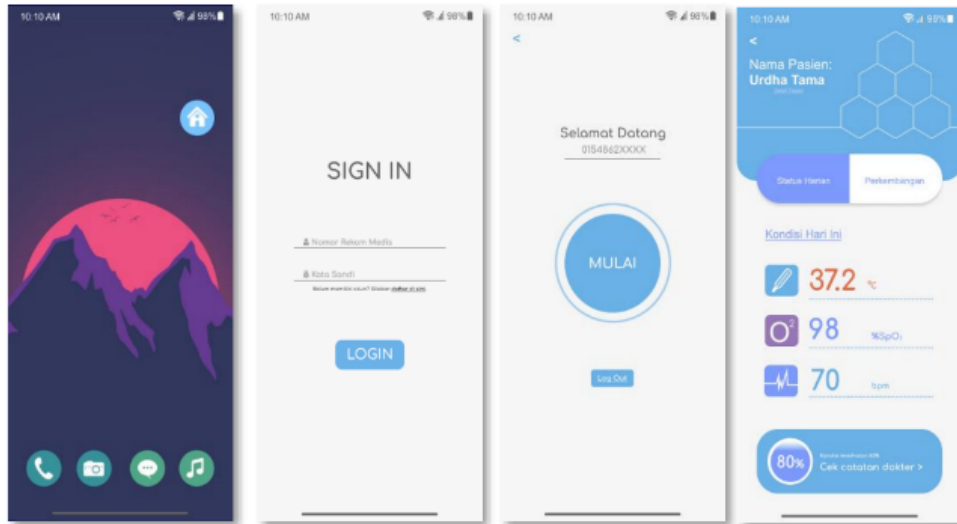

Figure 2 First Mockup

This stage is the stage where an analysis of predetermined problems is carried out, so a solution is formulated in the form of a monitoring system for the patient's condition through the application as a medium for transferring information from the hospital to the patient's family and from the patient's family to the hospital. Afterward, the process continued with the 'define' stage, which is the stage of designing a mockup based on the steps that have been done before.

In the mockup design in the form of a mockup application, the user interface or user interaction screen display is designed using features that can support patient monitoring in hospitals. There are several features in the design of the application, including monitoring body temperature, blood oxygen levels, blood pressure, monitoring daily conditions, and patient history or recovery. The mechanism of the patient condition monitoring application is that nurses or health workers can input, or record data related to the patient into the application, so that the patient's family can see the patient's condition in real time directly (per day) and be able to monitor the patient's progress.

On the next stage, which is prototype, the application mockup is tested to find out the strengths and weaknesses of the product. Identification of strengths and weaknesses is conducted by disseminating questionnaires to respondents which are hospital employees. The results of the prototype stage carried out using the Quality Function Deployment stage are need statements which are then presented in the form of a house of quality.

House of Quality

Quality Function Deployment (QFD) is a method that focuses on customer satisfaction. The Quality Function Deployment is an established tool to help interpret customer requirements from the voice of the customer into technical requirements of the product, process or service that will become the final design target (Furterer, 2012). The following are need statements obtained from the initial stage of Quality Function Deployment:

Table 1 Need Statement

Index	Need Statements
V1	The patient's family gets help regarding the action of the patient
V2	There is information related to the patient provided by the doctor or the hospital
V3	Information relating to the progress of inpatients

Index	Need Statements
V4	Complete medical data presented to the complete patient family
V5	There is information related to patients that can be accessed by the hospital
V6	The patient's family gets notes or messages from the doctor or nurse

Quality Function Deployment, the process starts from distributing questionnaires to collect need statements. The result of this method is the House of Quality matrix that connects consumer needs with design steps. There are ranks or weightings on each user requirement that serve to prioritize each user requirement. House of Quality can be seen in the picture below:
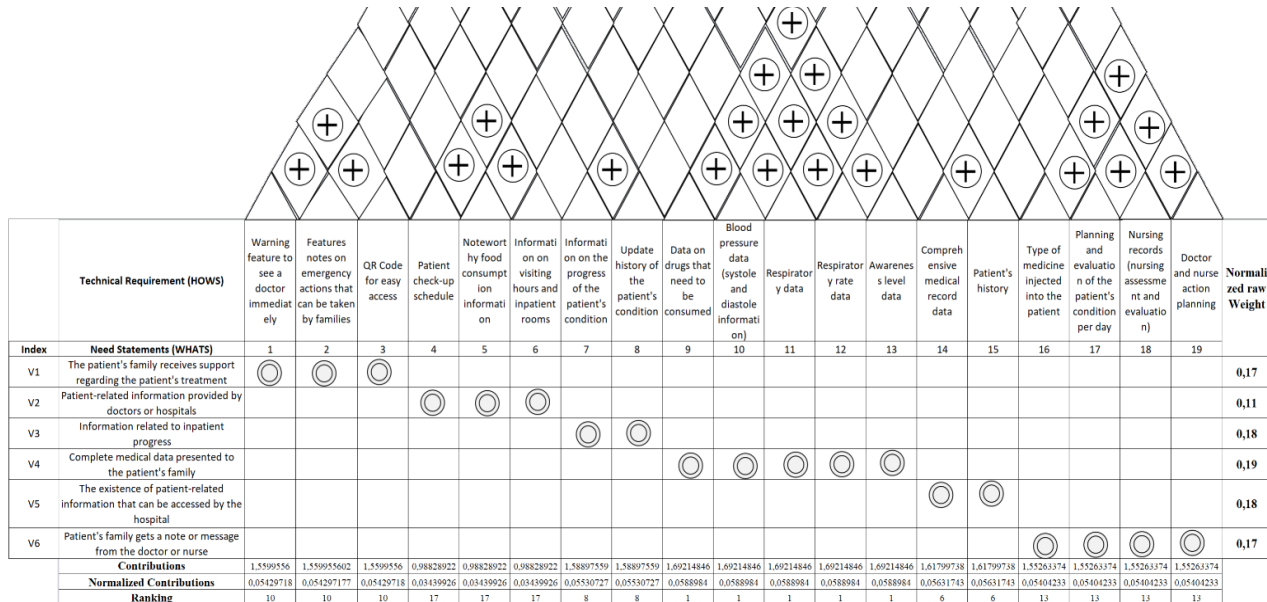

Figure 3 House of Quality

Based on the results of the house of quality above, the sequence of technical requirements can be used as a guide in developing the product. The following is the sequence of technical requirements:

Table 2 Technical Requirement

Technical Requirements	Priority
Data on medications that need to be taken	1
Blood pressure data (systole and diastole information)	1
Respiratory data	1
Respiratory rate data	1
Consciousness level data	1
Complete medical record data	2
Patient history	2
Information on the development of the patient's condition	3
Update history of the patient's condition	3
Warning feature to see a doctor immediately	4
Note feature about emergency actions that can be taken by the family	4
QR Code for easy access	4
Type of medicine injected to the patient	5
Planning and evaluation of the patient's condition per day	5
Nursing records (nursing assessment and evaluation)	5
Doctor and nurse action planning	5
Patient check-up schedule	6
Information on food consumption that needs to be considered	6

Technical Requirements	Priority
Information on visiting hours and hospitalization rooms	6

The technical requirements in the table above are the translated results of the need statement obtained in the empathy phase of design thinking. The application of design thinking provides an opportunity in product development to understand the situation experienced by users directly. However, design thinking is not incorporated with a tool that can help the process of determining the technical needs of the product. The role of Quality Function Deployment in this design thinking framework is to provide tools that are competent in defining the technical needs of the designed product.

Final Mockup

The prototyping process begins with identifying deficiencies by involving competent respondents in the health sector, namely hospital employees. Based on the product mockup that was made at the ideate stage, it turns out that there are still deficiencies in the product so that the prototype stage aims to improve the product concept before entering the testing stage. The process begins with identifying the needs of the respondents so that technical requirements can be generated according to the needs of the respondents in accordance with the previous sub-chapter. After identifying technical needs and prioritizing these technical needs, then product improvements are made. The following are product improvements:
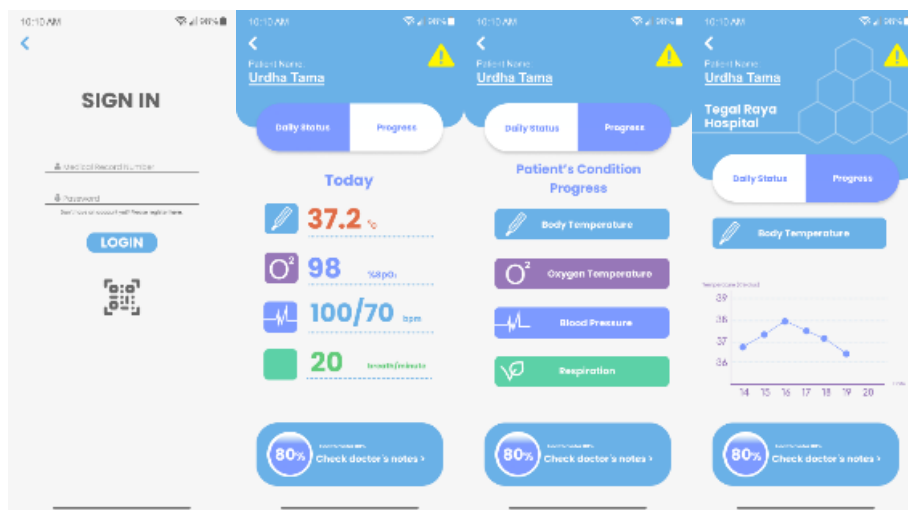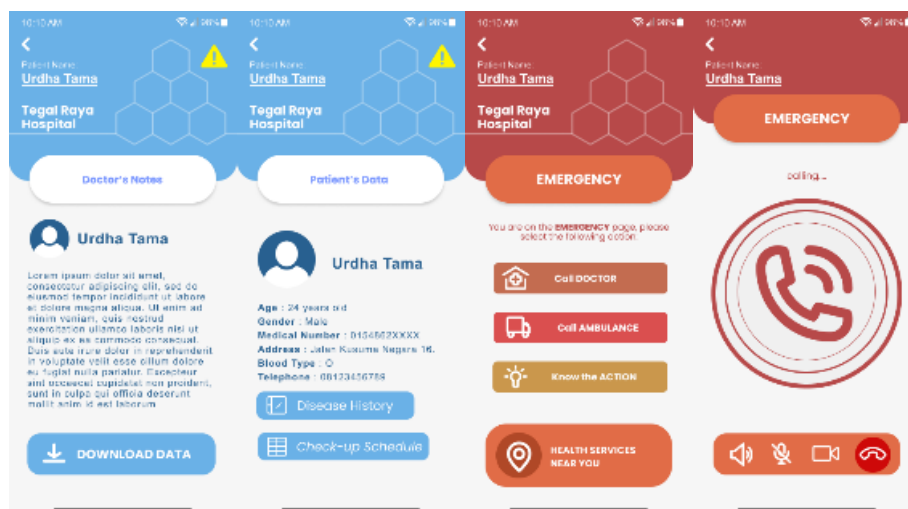

Figure 4 Final Mockup (1)

Figure 5 Final Mockup (2)

DISCUSSION

The main focus of QFD as a method or approach is used to improve services, especially in the service industry. Thus, the service industry needs to implement it, including hospitals as health service industries. QFD can produce outputs in accordance with consumer tastes and desires. This method requires special attention at each stage. Through HoQ, the implementation of QFD becomes more structured and valuable so that the results obtained will be better. Many previous studies related to smart monitoring systems have been conducted with an IoT implementation approach. Smart monitoring and IoT (Internet of Things) are two related concepts that are increasingly used in various industries and applications. In the health sector, smart monitoring and IoT can be used to monitor patient health and provide real-time feedback to health care providers, thus enabling faster and more effective treatment. This research uses a different approach. The process of designing smart monitoring system products is focused on identifying user needs using the integration of design thinking and Quality Function Deployment.

The integration between design thinking approach and Quality Function Deployment has proven effective in several studies with the aim of designing an intangible product. According to wijayanto et al, the design thinking approach used in the process of designing an application for handling reports on theft of goods has proven to have a positive response after usability testing. The application development process carried out by Wijayanto et al starts from the empathy, define, ideate, prototype, and test stages (Wjiayanto, Triyudi, & Rubhasy, 2021). 'Ideate' process is defined as the process of creating an application according to the context of a predetermined problem (related to the theft report), thus the output at this stage is the storyboard of the application to be designed (Wjiayanto, Triyudi, & Rubhasy, 2021). While according to Ilham et al, this ideate stage is defined as a brainstorm process with the aim of generating ideas or solutions to overcome predetermined problems so that the output at this stage is the features that must exist in the product to be designed (Huang, Mao, Liu, & Song, 2022).

According to Meinel et. al (2018), they conducted a comparison of these two product development methods, namely design thinking and Quality Function Deployment and the result was that the application of design thinking helped novice teams to produce more creative product concepts than when the current standard was applied (Meinel, Wagner, Baccarella, & Voigt, 2018). In general, these findings are in line with the effects proposed in previous research on Design Thinking (Wattanasupachoke, 2012). In addition, it was shown that a user experience-based approach to product development, such as Design thinking, leads to overall better performance in generating more creative concepts, Meinel et al.'s research also showed statistically significant results that design thinking positively affects the feasibility, relevance, and specificity of the concepts generated. This implies that integrating user experience-based approaches, such as design thinking, into the product development process can improve performance and lead to more creative concepts. Meinel et al.'s research shows that by adopting design thinking principles, product development teams can create concepts that are not only more feasible, relevant and specific, but also more innovative and unique. Design thinking

encourages teams to approach problems from a fresh perspective and consider various factors that can affect the user experience, such as emotional response, usability, and accessibility. By focusing on the user experience during the product development process, the product development process can put more emphasis on user needs and preferences, leading to the creation of products that are more likely to meet those needs and preferences. Ultimately, the integration of design thinking into the product development process can lead to better outcomes for users.

In this study, the output of the ideate process is a product mockup as stated by Yulius & Putra, the ideate process is the process of starting to design products that can provide solutions to problems. Although some previous studies have different definitions related to the process of design thinking, in general, the framework used can have effectiveness in the product design process (Yulius & Putra, 2021). The final design thinking process is testing, which is carried out with usability testing. Usability is the extent to which a product can be used by specific users to achieve specific goals with effectiveness, efficiency, and satisfaction in a specific context of use. So, Usability testing can be considered an evaluation process carried out to measure the extent to which a product or system can be used easily, effectively, and satisfactorily by users. The main purpose of usability testing is to identify problems that users may encounter when using a product or system, as well as improve inadequate design and interaction. (Salvendy, 2012). The importance of usability testing is related to the fact that good usability is very important in the scope of the product. If a product is difficult to use, users will struggle to use the product or even leave it. Clear communication between users when using the product is very important, and if users have trouble finding information or get lost when using the product, they will leave the product. No one wants to spend time learning how to use a product. Therefore, leaving a site that is difficult to use is a natural response of users, so usability testing is important (Nielsen, 2012). The existence of usability testing is very helpful for developers to find out the suitability between user needs and features contained in the product. Based on previous research conducted by Supriyatna (2018), said that usability testing has a role to find out how appropriate the product that has been designed to meet user needs. Usability testing is important for new products to determine the level of product usability based on user preferences (Supriyatna, 2018). The following table is some of usability testing statements:

Table 3 Usability Testing

Number	Usability Testing Questions
1	This app provides an acceptable way to deliver healthcare services.
2	This app will be useful for my healthcare practice.
3	This app improves my access to deliver health care services.
4	..

Usability testing questionnaires were distributed to 41 respondents who are stakeholders in one of the hospitals. The selection of respondents who are stakeholders in the hospital is because the position occupied by the respondent has direct contact with patients and one of their responsibilities is to provide data related to patients. In this usability testing, respondents were given a video of how the patient monitoring system application mockup works. After the respondent saw the video, the respondent answered the eight statements that had been provided with the answer options presented on a Likert scale. Liker scale is presented with four choices ranging from number 1 which means strongly disagreeing with the statement to number 4 which states strongly agreeing with the statement provided.

Based on the questionnaire results, 69% of respondents chose number 4 which means they strongly agree with the statement, 24% of respondents chose number 3 which means they agree with the question, and 7% of respondents chose number 2 which means they disagree with the statement. Based on the usability testing questionnaire above, the average respondent has the option to agree to strongly agree, which proves that this application is feasible to implement and realize because the respondent feels that this application is easy and can be a solution to the problems that have been determined.

CONCLUSION

The hospital feels a positive impact with the existence of a product in the form of an application that can be used as a medium for conveying information from the hospital to the patient's family and

vice versa. The existence of this application can provide a convenient way for hospitals the delivery information to patient families, provide easy access for hospitals and families regarding patient conditions, and facilitate communication between patients and families to the hospital and vice versa.

Based on empathizing and define the process, several features are determined in this application including the "patient personal data" feature, "patient condition", "patient condition development", and "doctor's notes". However, in the prototyping process identification of product deficiencies was carried out so that several features were added including "alerts", QR Code, "checkup schedule", more complete data presented related to patients, and emergency service features.

The design process is carried out using an integration between design thinking approach combined with the Quality Function Deployment method. This research can also represent the impact of design thinking on more traditional product development approaches derived from a user preference-centered concept generation perspective, namely Quality Function Deployment. By integrating the design thinking approach with the Quality Function Deployment method, the design process can become more effective at meeting user needs, ultimately leading to the development of high-quality products. This research highlights the importance of incorporating a user preference-centered approach to concept generation, as this can lead to the development of products that are more likely to solve real-world problems. The integration of design thinking and QFD provides a structured framework, thus enabling a more comprehensive approach in the context of creating products that meet user needs. Overall, the application and approach of this method can be used in the product development process to create innovative and effective solutions that meet user needs and preferences. The implementation of these approaches and methods is proven to produce products that can solve problems.

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