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Optimizing Coagulation Profile E-Reporting: A Design Thinking Perspective on Healthcare and Technological Integration

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***Abstract*—The coagulation profile report is crucial for assessing blood clots and diagnosing various bleeding disorders. Key metrics in these reports include the international normalized ratio (INR), activated partial thromboplastin time (APTT), platelet count, and fibrinogen levels. Traditionally, these reports have been delivered through paper-based methods, which often face significant challenges such as human errors, delays in distribution, and limited accessibility. To address these issues, this preliminary investigation explores integrating technology into the reporting process for coagulation profiles. By leveraging a design-thinking approach, the study aims to understand the needs and preferences of stakeholders and users. This approach includes creating personas to represent different user types, mapping their experiences through empathy and journey maps, and generating and testing ideas through ideation and prototyping. The core objective of the study is to develop a mobile application that simplifies and enhances the reporting process of coagulation profiles. This application is designed to integrate seamlessly with Electronic Medical Record (EMR) systems, providing real-time notifications to healthcare providers when laboratory results are available. The proposed solution aims to improve the timeliness and accuracy of reporting, facilitating better patient care and more efficient workflows. The paper details the components of this solution, including the prototype design and the validation procedures used to ensure its effectiveness. The study seeks to revolutionize how coagulation profiles are documented and communicated in healthcare by adopting a digital reporting system.**

***Keywords*— Coagulation; mobile application; prototyping; design thinking; technology integration.**

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I. INTRODUCTION

Amidst the digital transformation era, healthcare systems consistently seek inventive approaches to improve the delivery of patient care [1]. The reporting of coagulation profiles is essential for diagnosing and treating different bleeding disorders, coagulation abnormalities, and thrombotic events [2]. Nevertheless, traditional paper-based reporting systems frequently provide considerable difficulties, such as manual data entry errors, delayed results distribution, and restricted availability. Therefore, utilizing technology to optimize the reporting of coagulation profiles can overcome these limitations and revolutionize the documentation and sharing of laboratory results [3]. This preliminary investigation seeks to evaluate the practicality and potential benefits of incorporating technology into the procedures for reporting coagulation profiles. This study establishes the groundwork for future research to thoroughly investigate the advantages of technology in enhancing coagulation profile reporting and ultimately enhancing patient outcomes through the analysis of electronic platforms, data interoperability, and efficient workflows.

Design Thinking has been applied as a methodology to tackle the problem of delayed communication of coagulation profile results for pediatric patients undergoing therapeutic intravenous (IV) Heparin treatment after cardiac surgeries in the Pediatric Cardiac Intensive Care Unit (PICU). The objective was to comprehend the requirements and difficulties faced by primary users impacted by communication discrepancies between two hospital-wide systems, specifically the Laboratory Information System (LIS) and

Electronic Medical Record (EMR). The primary users comprised critical care nurses, attending physicians, and laboratory representatives. Several tools, including Persona Canvas, Empathy Map, and User Journey Map, were used to understand and document the characteristics and experiences of each user for analysis. The interviews and workflow observations analysis uncovered a significant issue: a unified system notifying healthcare providers when test results are accessible in the electronic medical record (EMR). Delays and inefficiencies in delivering quality care and ensuring patient safety were identified as the fundamental problem that needs to be resolved.

This paper presents preliminary research to enhance current operations by detailing its components, prototype design, and validation process. Inspired by the necessity of providing timely notifications to healthcare providers regarding laboratory result availability in the EMR, the proposed solution seeks to address these challenges. The paper is structured as follows: Section 2 provides background information and discusses relevant topics concerning technology for coagulation profiling and design thinking in healthcare. It is followed by a subsection elaborating on the design thinking methodology encompassing data collection, analysis, and design. Section 3 presents the Coagulation Profile E-Reporting prototype design proposal. Finally, Section 4 concludes with a summary of the research.

II. Materials and Method

Coagulation profile e-reporting is crucial in diagnosing and managing various hematological disorders. With technological advancements, there is a growing need to explore innovative approaches to enhance the efficiency of coagulation profile reporting. This literature review aims to examine the existing research on harnessing technology and applying a design thinking approach to improve the process of coagulation profile e-reporting.

A. Technology-enabled Coagulation Profile Reporting

In recent years, there has been a significant rise in technology adoption for healthcare applications. Digital platforms and electronic health records (EHRs) have been utilized to facilitate efficient reporting of coagulation profiles. Studies have shown that electronic reporting systems improve accessibility, reduce errors, and enhance communication between healthcare professionals [4], [5]. Technology-enabled coagulation profile reporting has become crucial to diagnosing causes of hemorrhages, developing anticoagulant drugs, assessing bleeding risk in extensive surgery procedures and dialysis, and investigating the efficacy of hemostatic therapies. In this regard, advanced technologies such as microfluidics, fluorescent microscopy, electrochemical sensing, photoacoustic detection, and micro or nanoelectromechanical systems (MEMS/NEMS) have been employed to develop highly accurate, robust, and cost-effective point of care (POC) devices. These devices measure electrochemical, optical, and mechanical parameters of clotting blood, which can be correlated to light transmission or scattering, electrical impedance, and viscoelastic properties [6]. Recent advancements in microfluidic technology have empowered researchers to replicate the blood coagulation process under physiological conditions, enabling a detailed examination at the molecular level. Fluorescent imaging techniques and fluorescent probes within microfluidic channels have furthered our understanding of interaction dynamics and defect origins, offering remote observation, precision, and multiplexed analysis capabilities [6]. Real-time point-of-care (POC) measurement of coagulation parameters can improve patient outcomes in clinical settings such as surgical and minimally invasive cardiac procedures, critical care units, and emergency departments [7].

B. Design thinking in healthcare

Design thinking is an iterative problem-solving approach that prioritizes user needs and experiences. Its application in healthcare has shown promising results in enhancing patient-centered care and improving workflow efficiencies. Consequently, the United States has implemented design thinking in its health systems by establishing dedicated centers that adopt design thinking principles to enhance patient care [27], [28]. Several studies have highlighted the benefits of design thinking in developing innovative healthcare solutions [8]. It is highlighted by [29] that design thinking fosters innovation in clinical and managerial contexts across various medical specialties. Furthermore, design thinking lends support to developing solutions tailored for low-resource settings. Compared to conventional expert-driven procedures, design thinking may provide treatments that are useable, acceptable, and effective [9]. Design thinking shares many principles with process improvement methodologies commonly employed in healthcare administration. These include emphasizing brainstorming, understanding user needs, and fostering collaboration [28]. Recent research reports the use of design thinking in various innovation projects across medical disciplines, including pediatrics, psychiatry, radiology, gastroenterology, cancer, orthopedics, and surgery, as well as in hospital operations and healthcare management [10]. Design thinking has proved to be a catalyst by involving patient-centric providers and IT specialists in solution development and creating a particular future preview and, thus, precise requirements [11].

C. Application of Design Thinking in Coagulation Profile e-Reporting

The utilization of design thinking is broadening in diverse contexts, extending beyond the confines of the coagulation profile. Another study by [31] outlines three design thinking constraints when managing disease outbreaks. Firstly, involving end users in the design process requires a significant amount of their time and active participation to co-create a solution. Another limitation is that focusing on user-centricity, especially when employing a "bottom-up" methodology to create a solution, can lead to partiality towards specific user personas in the design of the solution. Design thinking is often criticized in the literature for its lack of a clear definition, limited theoretical foundation, and potential to restrict innovation compared to other design techniques. Incorporating intended users and stakeholders at an early stage of development can provide an understanding of medical needs, technology perception, and interface preferences. A previous study [17] conducted a user-centered design (UCD) approach through focus groups that involved asthmatic patients and clinical care providers during the

application's development. The study reveals that both groups provide different attributes, where patients prioritize low-cost and emergency contacts. In contrast, care providers prioritize patient monitoring, EHR integration, peak flow measurements, and pharmacy connectivity. Using these requested and discovered features, the study incorporated them into the prototype application. A study by [18] redesigned the user interface to target a cohort of elders and middle-aged persons, which involved them through eye activities using Kinect motion sensing equipment. The study proposes a systematic usability testing method using physiological and psychological data to improve the usability of products for the elderly. It suggests specific suggestions for motion exercise system designers and encourages the use of the proposed method by other researchers. The method can be customized to evaluate other healthcare devices or systems. Meanwhile, research by [19] involved participants through semi-structured telephone interviews, which were then summarized into matrices for the analysis and identified key themes for the application intervention and its implementation characteristics. The study found that eliciting provider feedback at an early stage of development and incorporating the findings into interventions improves their effectiveness. Furthermore, a study by [30] outlines the components, prototype design, and validation procedure of a solution to improve current operations, which was motivated by the requirement to promptly notify healthcare practitioners about the availability of test results in the EMR.

D. Coagulation Profile e-reporting Methodology

This study incorporates the Design Thinking (DT) process as a research methodology component. Its widespread usage derives from its ability to foster user-centered innovation by emphasizing empathy, collaboration, and iterative processes. This results in solutions that precisely cater to the user's needs. DT, or Design Thinking, is a method that involves five stages: (i) empathize, where the goal is to understand consumers or users; (ii) define, which helps identify requirements; (iii) ideate, where ideas are generated, (iv) prototype, which involves developing and sampling a solution, and (v) test, where the solution is evaluated, and feedback is obtained from customers or users. This methodology facilitates thoroughly comprehending users' viewpoints to create effective and efficient solutions.

1) Persona, Empathy Mapping, and Journey Mapping Analysis: Persona, Empathy Mapping, and Journey Mapping Analysis are three techniques employed in gathering requirements. Persona is a method used to comprehend the user group and examine the needs and demands of users [20]. Empathy Mapping is a method to gain insight into the user's emotional state and sentiments [21]. This methodology facilitates the team in comprehending the user's viewpoint and tailoring the product's design. Journey Mapping Analysis is a method employed to learn the entirety of the user's journey, spanning from the initial stage to the final stage [22]. This aids the team in pinpointing areas of difficulty and tailoring the product's design to address them. The first step entails collecting feedback from primary end users of the current system by employing Personal Canvas, which encompasses interviews and observations in the PSICU care procedures.

Three (3) key personas directly involved in the problematic process are identified, and each persona is provided with their persona map, empathy map, and journey map. The personas are informed about their selection and willingly participate by completing the Personal Canvas. Subsequently, face-to-face interviews are conducted to gather information for the empathy map. The journey map template is employed, and discussions are held among personas, users, and customers to gather all necessary information for completing the journey map. The findings from all the persona maps, empathy maps, and journey maps are analyzed to derive insights.

Table 1 summarizes the insights gathered from the persona, empathy, and journey mappings. This information supports the application requirements and design.

TABLE I
REQUIREMENT GATHERING USING PERSONA, EMPATHY, AND JOURNEY MAPS

Name	Position	Interview Summary
Prasis Singh	Critical care nurse	Mr. Prasis encountered technical obstacles that hindered the optimal healthcare delivery in the Pediatric Intensive Care Unit (PICU). One such obstacle was that doctors provided verbal orders for blood tests, which could easily be overlooked in the fast-paced environment. To enhance accuracy and efficiency, it is recommended that the electronic medical record (EMR) system be utilized for test orders. In addition, drawing blood from critically ill pediatric patients presents challenges, often resulting in inadequate samples, lysed samples, or repeated pricking that causes discomfort to the patient. The Accuvein Finder, a device for visualizing veins, can significantly assist this process. However, due to budget constraints, its acquisition is often considered a luxury rather than a necessity. The responsibility for maintaining the pneumatic tube system used for blood sample transport lies with facility management. Frequent breakdowns cause delays in sample delivery, thereby prolonging turnaround times. Ensuring prioritized maintenance of the tube system is crucial to ensuring efficient and timely delivery of samples to the laboratory.
Dr Hala Ismail	Pediatric Cardiothoracic: Surgeon	Dr. Hala, an experienced pediatric cardiothoracic surgeon at Prince Sultan Cardiac Center, is known for his maturity and positive demeanor. His primary goals involve performing complication-free cardiac surgeries and closely collaborating with the nursing team to provide optimal postoperative care. Dr. Hala knows ICU nurses' challenges, such as heavy workloads, staffing shortages, and budget constraints. He expressed hope that the hospital management would promptly address these issues. Upon reviewing the journey map, Dr. Hala expressed concern regarding the possibility of ICU nurses forgetting to inform him about coagulation test results. He suggests that the hospital management implement a result notification system to ensure timely communication of test results to him. Such a system would also alleviate the burden on nurses, who currently have to track and trace the results manually. Dr. Hala emphasizes receiving prompt notifications to facilitate efficient decision-making and enhance patient care.

Name	Position	Interview Summary
Ms. Mona Elkady	Lab Manager	Ms. Elkady, an experienced lab manager with 8 years of service at Prince Sultan Hospital, expresses her frustration regarding the absence of equipment upgrades during her tenure. Despite increased patient load, the laboratory unit has witnessed minimal improvements since the hospital's establishment in 1978. Inadequate turnaround times are attributed to insufficient senior lab technicians and outdated machines that struggle to handle the volume of blood tests. Rather than utilizing an automated system, the manual loading of blood samples into analyzers is still required. Furthermore, the current coagulation profile analyzer can process only a limited number of samples simultaneously. In contrast, the state-of-the-art analyzer shown in Figure 5 boasts a significantly higher throughput of 390 tests per hour. Due to budget constraints, requests for new equipment often go unnoticed. One major technical challenge faced by Ms. Elkady is the absence of an automated workflow where analyzer results can be directly input into the electronic medical record (EMR) system via a connection module. As a result, lab technicians must manually enter results into the EMR, leading to time consumption and potential errors. Ms. Elkady hopes to integrate an automated notification system, along with an acknowledgment of receipt, into the existing EMR system to streamline processes and enhance efficiency.

2) Idea Generation: After analyzing the empathy map and journey map for three essential stakeholders - the pediatric cardiothoracic surgeon, critical care nurse, and lab manager - we have identified and combined the main issues faced by the primary users. The issues consisted of the manual process of nurses tracing lab results from the lab system, the delayed communication of coagulation test results to the pediatric cardiothoracic surgeon, and the challenges faced by lab technicians in contacting nurses to notify them about rejected coagulation profile test samples.

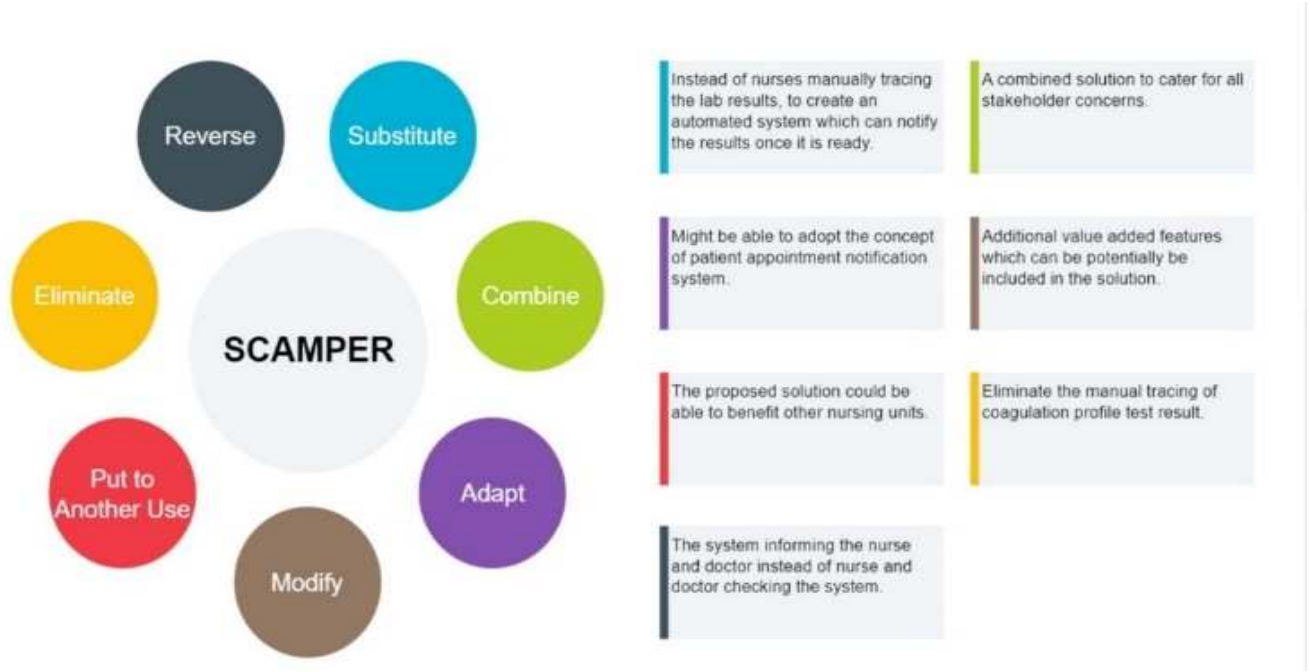

Fig. 1 Scamper

SCAMPER is utilized by [26] as a component of their design methodologies for microfluidic design. To address these problems, this study employed the SCAMPER technique (refer to Figure 1) to generate ideas and opted to substitute the manual tracing procedure with a mobile application. This solution seeks to address the identified concerns of the stakeholders and provide additional value-added features. The hospital's chief information officer played a role in developing a prototype of the desired mobile application.

The Lab Live Tracing System, a mobile application, will be implemented as a pilot project in the intensive care unit. If the application effectively resolves the stakeholders' initial concerns, it can be expanded to encompass other clinical domains. The application will be downloadable on both iOS and Android operating systems, enabling users to access it on their mobile devices.

The pilot project will provide unique user IDs and passwords to approved users, such as nurses, doctors, and clinical laboratory technicians who work in the intensive care unit. These credentials will be used to log into the system, guaranteeing the process of identifying and verifying the user's identity. The mobile application will be connected to the hospital's lab information system (LIS), allowing for the automatic presentation of completed blood test results within the application.

A notable characteristic of the application is its capacity to identify the nurse and doctor responsible for requesting the test and transmit notifications to them once the results are available. This addresses the problem of manual tracing encountered by critical care nurses. In addition, the application enables laboratory technicians to promptly inform the nurse if a blood sample is rejected, thereby necessitating the collection of a new sample.

In addition, the application features an integrated chat system that allows attending nurses and doctors to communicate and revise the patient's management plan using the most recent blood results. It also includes a reminder feature to streamline task execution and enhance patient management coordination among nurses and doctors.

The application includes a comprehensive bed board for the intensive care unit, which offers users specific patient information, including their name, age, diagnosis, attending consultant, and details of laboratory test results. Finally, the laboratory technician can use the application to directly communicate with the nurse or doctor on duty regarding crucial test result values or to notify them about blood samples that have been rejected. The Lab Live Tracing System mobile application offers a comprehensive solution to efficiently report coagulation profiles, facilitate stakeholder communication, and enhance intensive care unit patient care.

3) Prototype Design: Prototyping is the central technique used in design practices [23], [24]. The purpose of prototyping is to concretize a concept [25]. Prototypes are models created before the final product exists to represent the design. Figure 2 illustrates that an optimal prototype should go through multiple iterations to identify potential flaws before reaching its final version. The input and feedback from end consumers are crucial for the development of a product that is both practical and efficient. This study proposes creating a mobile application called Lab Live Tracing System (LLTS), which aims to enhance communication among users such as surgeons, critical care nurses, and lab technicians. This mobile platform will offer immediate access to blood test results and notify users about crucial values and sample inaccuracies.

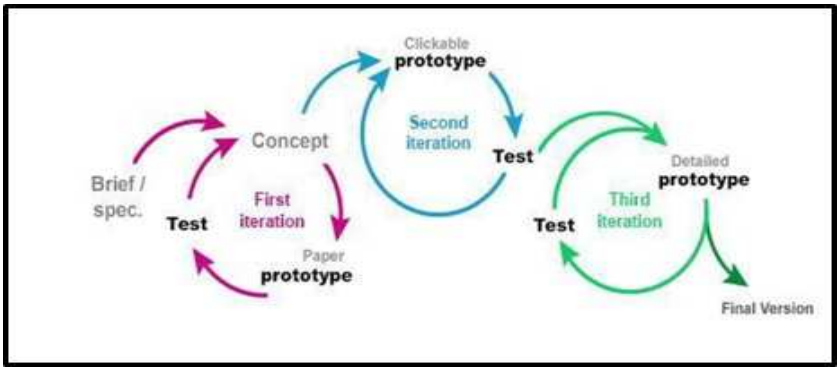

Fig. 2 Redesigning and Prototyping Iteration [23]

III. Results and Discussion

A. Prototype Design

The motivation for the proposed solution stemmed from a persistent challenge faced by healthcare providers in the PSICU. They lack awareness of laboratory results availability after processing and entering blood investigations into the LIS. Through the empathy journey, the team gained insights into the demanding and fast-paced environment of the PSICU, where post-operative patients require continuous observation and intensive care. Physicians and nurses in the unit face significant workloads, impacting their cognitive functions regarding coagulation profile results. A user-friendly alerting system called Lab Live Tracing System (LLTS) is introduced to address this. It offers real-time access to critical values in the Coagulation Profile, enabling timely adjustments to patient care, such as modifying IV Heparin dosages, ultimately enhancing workflow and improving the quality of care in the PSICU.

The users who will benefit from LLTS include critical care nurses, surgeons, and lab technicians. There is no existing notification system for critical values, requiring critical care nurses to regularly log into the Electronic Medical Record system to track Coagulation Profile results. However, the demanding work environment in the PICU can hinder this process and consume valuable time.

LLTS will offer a distinct solution by providing users access to patient results anytime and anywhere through their mobile devices. Lab technicians can alert PICU staff about critical values or sample errors, while staff nurses will receive real-time updates on test results. Surgeons will also communicate directly with staff nurses, allowing them to modify patient management plans accordingly.

This integrated mobile application system will deliver real-time updates to all healthcare professionals involved. LLTS facilitates seamless communication among stakeholders, promptly rectifying errors and critical values, ultimately saving crucial time and enhancing patient outcomes after surgery. Figure 3 depicts the application interface design for LLTS. The proposed application has six primary interfaces: an authentication page, a Staff-in-charge information page, a patient-ward board page, and a patient-critical value page. The authentication page allows authorized users to log in to LLTS. The authorized users can view and monitor the patients in the coagulation profile listing. Only authorized users can view and act on the critical value alerts. As a result, LLTS implementation enables authorized users to conveniently access patients' results using their mobile devices, ensuring availability anytime and anywhere. Lab technicians can promptly notify PICU staff of critical values or sample errors. Additionally, staff nurses receive real-time updates on test results, while surgeons can directly communicate with staff nurses and make necessary adjustments to patient management plans.

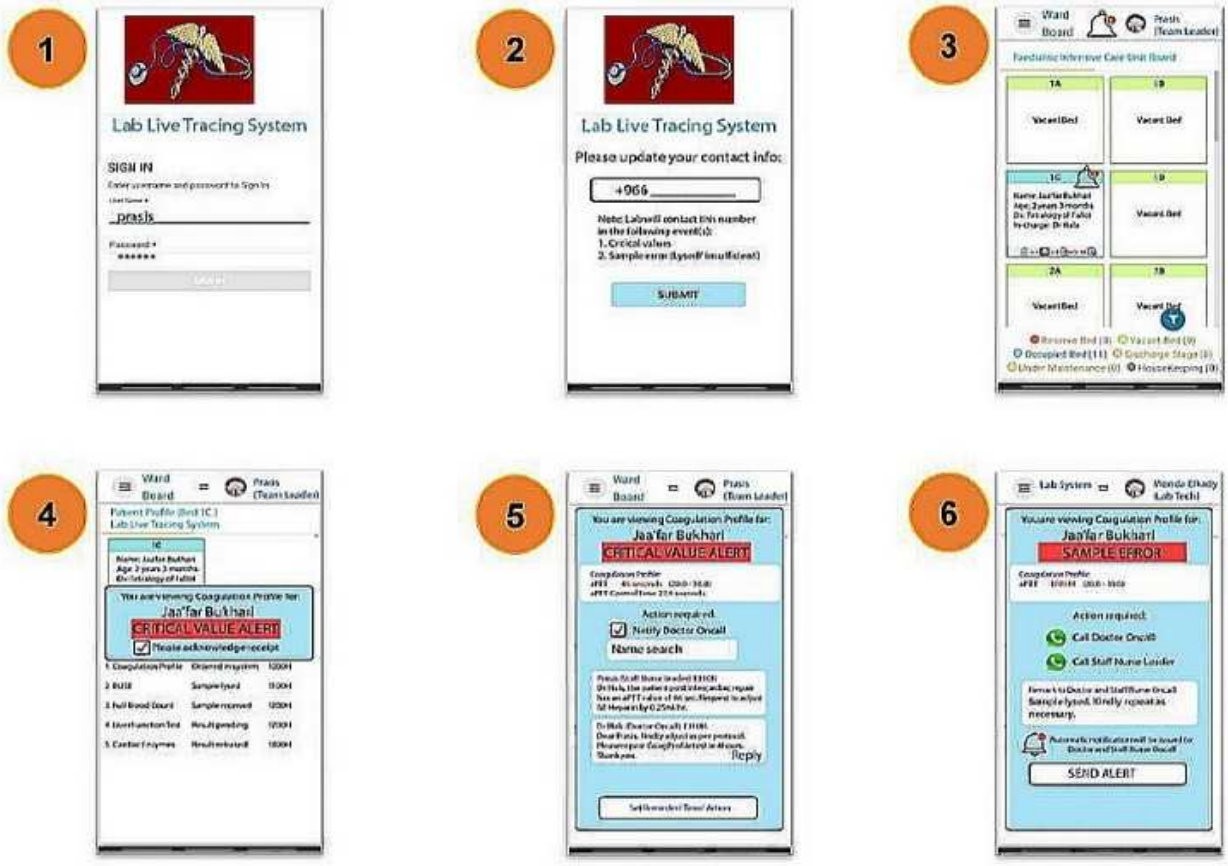

Fig. 2 Lab Live Tracing System Interface Design

Nevertheless, the proposed LLTS application could be limited by its reliance on personal mobile devices for access, which could introduce compatibility and security issues. In environments with diverse device types and operating systems, it may be difficult to ensure seamless functionality. Furthermore, excessive reliance on mobile devices may hinder the effectiveness of LLTS for staff unfamiliar with technology. In addition, network connectivity issues may disrupt real-time updates, delaying the transmission of vital information while monitoring the patients.

B. Prototype Value Proposition

This stage provides proposition and validation based on several questions.

1) What problem does your idea solve? There is no notification system for informing Pediatric Intensive Care Unit personnel (doctors and staff nurses) about critical values in the Coagulation Profile, which are crucial for patient care management. An innovative mobile application called Lab Live Tracing System allows users to access real-time results, ensuring prompt adjustments to critical patient care, such as modifying the dosage of IVI Heparin.

2) Who are your users? The Lab Live Tracing System will benefit critical care nurses, surgeons, and lab technicians.

3) How are users solving this problem currently? Currently, there are no notifications of critical value systems in place. Critical care nurses must log on to the Electronic Medical Record system regularly to trace Coagulation Profile results. The hectic work environment in the Pediatric Intensive Care Unit may hinder this process and take up precious time.

4) *How will your product solve the problem differently?* The Lab Live Tracing System will allow users to access patients' results anytime and anywhere using their mobile devices. Lab technicians can alert PICU staff to critical values or sample errors. Staff nurses will have real-time updates on test results. Lastly, surgeons can communicate directly with staff nurses and modify patient management plans accordingly.

5) Elaborate value propositions, features, and impact of your prototype (solution): This integrated mobile application system will enable real-time updates for all healthcare personnel. The Lab Life Tracing System enables seamless communication between all stakeholders. Any errors and critical values can be rectified quickly, saving crucial time and improving patient outcomes post-surgery.

Overall, the proposed mobile application provides immediate access to Coagulation Profile values in Pediatric Intensive Care Units, addressing the urgent requirement for timely notification. It focuses on critical care nurses, surgeons, and lab technicians, completely transforming the current procedure. This guarantees a quick reaction to critical values, improves patient care, and enables smooth communication among all involved parties. The system enhances workflows, reduces errors, and enhances patient outcomes by incorporating user-friendly features like instant alerts and mobile accessibility. Validation via prototype testing guarantees that the product meets the users' requirements,

optimizing its efficiency and usability in clinical environments.

C. *Prototype Validation and Feedback*

In some projects, an unproductive utilization of time and resources would be a product that achieves its objective goals but fails to gain popularity among end users. Hence, it is crucial to assess the product design through a validation procedure. A mobile application prototype is generated for the Lab Live Tracing System. The prototype is subsequently showcased to users to collect feedback and identify areas for enhancement.

Prasis – **Critical Care Nurse**

Feedback and comment:

1. Clean user interface
2. Pleasing to the eyes
3. Critical value notifications can be extended to other tests
4. Lack feedback to lab (notification to lab staffs once sample is sent)

Dr Hala Ismail – **Surgeon**

Feedback and comment:

1. Ability to reply in app is commendable
2. Lack ability to order tests from app
3. Lack ability to chat with/ call lab staff in app (query on results/ turn-around-time)

Mona Elkady – **Lab Manager**

Feedback and comment:

1. Ease of notifying/ calling doctor or Staff Nurse on call
2. Person-in-charge name to be displayed in application
3. To add on ability to view tests ordered by whom
4. Lack function to snap photo(s) evidence in the event of mislabeling/ clotted blood samples

Fig. 4 Feedback from 3 persona

Figures 4 and 5 show feedback from the users who test and validate the prototype. The prototype received favorable feedback for its simplified interface and prompt notifications of critical value. Users value the app's functionality in responding to and receiving messages from medical professionals. Nevertheless, it was observed that there was a noticeable absence of communication from the laboratory and insufficient proof of blood sample documentation, indicating potential areas that could be enhanced.

3 Good Things:

1. Clean and tidy user interface.
2. Comprehensive functions available in-app (able to view test status, test results, and notification of results).
3. Ability to communication between lab staffs, staff nurses, and doctors. In-app chat and call functions are added bonus.

3 Improvements:

1. To consider adding function of ordering tests directly in the mobile application. This added functionality will improve efficiency of both staff nurses and doctors.
2. To consider adding critical value notification for other lab test results besides Coagulation Profile.
3. To consider adding function to call or chat with lab staff directly from mobile application. This will reduce the hassle of calling lab services over landline.

Personal Reflection:

1. Users prefer a clean and pleasing user interface compared to the complex version in their existing desktop Electronic Medical Record (EMR) system. Designing an application with comprehensive functions while remaining user friendly can be a challenge.
2. The purpose of the mobile Lab Live Tracing System (LLTS) is to facilitate tracing and notification of coagulation profile results. However, users demand for more functions along the design process. It is crucial to manage the expectations of users and adhere to initial design objectives. Additional functions may be included if they do not deviate too far from project goals.
3. End users are ultimately the ones using the mobile application. Their unique views and feedbacks are important to ensure that the final product usability is optimal.

Fig. 5 Extended Feedback from 3 persona

D. Discussions

The study investigates the use of Design Thinking (DT) methodology to tackle operational difficulties in Pediatric Intensive Care Units (PICUs), specifically in the development of the Lab Live Tracing System (LLTS). The research utilizes techniques such as Persona, Empathy Mapping, and Journey Mapping Analysis to deeply understand stakeholders' specific needs and challenges. LLTS, designed as a mobile app, aims to simplify communication and provide immediate access to important Coagulation Profile values, specifically for the fast-paced and ever-changing PICU environments. LLTS undergoes an iterative prototyping process, which is guided by user feedback. This process helps LLTS adapt to the specific needs of its end users. The focus is on using empathy-driven design to drive innovation in healthcare.

The utilization of LLTS highlights the capacity of user-centered methodologies to tackle intricate issues in healthcare provision. The DT methodology facilitates the creation of solutions specifically designed to meet the distinct requirements of PICU settings by promoting collaboration, empathy, and iterative problem-solving. LLTS is a promising tool that can enhance workflow efficiency, decrease errors, and ultimately improve patient care outcomes. Nevertheless, the study also emphasizes the perpetual nature of design processes, requiring constant repetition and verification to guarantee the solution's efficacy and smooth incorporation into clinical practice.

IV. Conclusion

As a high-priority section in the Pediatric Intensive Care Unit (PICU), the complex workflow structure presents substantial dangers of human error, especially when handling abnormal laboratory test results. Failure to promptly acknowledge or respond to these findings could result in diagnostic inaccuracies, potential patient harm, and legal liabilities. This study promotes the implementation of LLTS, a mobile application created using a design-thinking framework. The research determines the necessity of an automated notification system for healthcare providers by utilizing persona development, empathy building, and journey mapping processes. This system would promptly alert them to abnormal results, enabling efficient patient management in the PICU. Requiring confirmation of test result reception improves responsibility and improves patient care procedures. To effectively address safety concerns, it is essential to implement a comprehensive intervention that combines human-computer interaction with a dependable tracking system for notifying test results. End users' attitudes, perceptions, and knowledge are essential in maximizing the benefits of health information technology (HIT) innovation and improving healthcare quality.

For future work, it is recommended that LLTS be prioritized to achieve smooth integration into current PICU workflows and enhance user acceptance. Ongoing cooperation with end users is crucial to meet changing needs and preferences, promoting a constant enhancement culture in healthcare provision. In addition, research should investigate the scalability of LLTS to clinical settings outside of the PICU, considering the broader implications for patient safety and the coordination of care across healthcare facilities. Finally, assessing the lasting effects of implementing LLTS on clinical results and patient contentment can offer a valuable understanding of its efficacy and guide future improvements to optimize healthcare delivery procedures.

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