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Strengthening Public Child Healthcare: Development of an Immunization Management Information System for a Local Community in Southern Mindanao, Philippines

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Abstract

While the private healthcare sector rapidly embraces technological advancements, public and local communities struggle to keep pace with these innovations. Community health personnel's reliance on outdated manual methods for managing children's immunization records hinders timely updates and impedes the creation of reliable vaccination schedules, creating obstacles in providing accurate services to the growing young population. To address these challenges, the researchers developed an Immunization Management Information System, employing the Evolutionary Prototyping Software Development Model, which allowed for iterative improvements and customization to meet specific requirements. It incorporates technologies such as a centralized database, a web-based interface, and Short Message Service notification functionality to automate immunization management tasks. Healthcare professionals can record and track immunization details, manage vaccine inventory, generate reports, and send notifications to parents about upcoming immunization schedules. The results demonstrated a system that streamlines and enhances the management of immunization records and processes at the health center, ensuring efficient and timely delivery of services. Discussions on the system's technological features and future research directions are provided, encouraging Information System scholars to contribute to impactful research and development.

Keywords: *Immunization Management Information System, child immunization records, centralized database, Evolutionary Prototyping Software Development Model*

Introduction

Immunization significantly reduces the incidence of vaccine-preventable diseases (VPDs) and saves countless lives worldwide (Orenstein & Ahmed, 2017). The administration of vaccines represents the most effective tool for preventing certain diseases, and vaccination schedules ensure that individuals receive protection at the appropriate ages and times. According to the World Health Organization (WHO, 2019), immunization annually prevents 3 to 5 million deaths worldwide due to VPDs. Moreover, immunization is crucial in creating herd immunity, reducing disease transmission, and safeguarding vulnerable groups who cannot receive vaccinations (Iyer, 2021). Additionally, immunization programs have actively prevented outbreaks of highly contagious diseases like measles and polio, demonstrating the substantial impact of vaccines on global disease prevention (Blanc et al., 2024).

The Disease Prevention and Control Bureau (DPCB) of the Department of Health (DOH, 2020) manages and implements the Expanded Program on Immunization (EPI) in the Philippines, which began in 1976, added polio, measles, and tetanus toxoid for pregnant women, and also estimated vaccine coverage and monitoring of incidence and mortality of the six target diseases. Morbidity and mortality due to VPDs have declined significantly after the introduction of the EPI. In the early 1980s, thousands of VPD cases were recorded yearly, particularly for measles and pertussis. By the mid-1990s, the number of VPD cases and deaths declined sharply. The Philippines was certified to have eliminated Polio in 2000 and maternal and neonatal tetanus in 2017 (Ulep & Uy, 2021).

The EPI is mandated by Republic Act No. 10152, also known as the Mandatory Infants and

Children Health Immunization Act of 2011. The law requires the government to establish a comprehensive, mandatory, and sustainable immunization program for vaccine-preventable diseases for all infants and children. It empowers the government to provide routine vaccines at public health centers and other facilities, significantly contributing to improved childhood survival rates and increased life expectancy in the Philippines.

Routine vaccines for children aged 0 to 1 are administered free of charge at barangay health centers, aiming for a target coverage of 95%. The government provides these routine vaccines without cost at public health centers. The DOH leads extensive public awareness campaigns to educate the populace about the importance, safety, and benefits of vaccines. The agency actively encourages the public to prioritize immunization against vaccine-preventable diseases using vaccines such as Measles, Rubella, and Oral Poliomyelitis Vaccine (MR-OPV). The National Immunization Program, initiated in 1976 in collaboration with the WHO and the United Nations International Children's Emergency Fund (UNICEF), seeks to reduce morbidity and mortality caused by common vaccine-preventable diseases like tuberculosis, polio, diphtheria, tetanus, pertussis, and measles (Reyes et al., 2021). The program offers secure and effective vaccines tailored for newborns, infants, older children, pregnant women, and senior citizens.

According to UNICEF's 2021 report, the Philippines was listed as one of 10 countries with the highest number of zero-dose children worldwide (UNICEF Philippines, 2022). In June 2021, the Philippines ended the polio outbreak by vaccinating 11 million children during the COVID-19 pandemic. However, 1.5 million Filipino children still need the polio vaccine. The country has high-risk areas in 67 out of 81 provinces and 71 out of 96 cities. Moreover, a study by Reyes et al. (2021) revealed fluctuating coverage over the years in the Philippine National Demographic and Health Survey 2017 (NDHS) (Ulep & Uy, 2021). The percentage of children aged 12 to 23 months who received all basic vaccinations increased from 72% in 1993 to 80% in 2008 but steadily declined from 77% in 2013 to 70% in 2017. In light of this, UNICEF has urged the government to prioritize strategies targeting zero-dose children and to integrate routine immunization services to strengthen healthcare delivery. Achieving the 95% target coverage for routine childhood vaccines requires reliable access to primary healthcare services and a robust vaccine supply chain, along with accurate immunization records for infants and children.

One critical tool in strengthening healthcare delivery is the adoption of health information technology (HIT). Several studies, including a paper by Blavin et al. (2013), highlight that Electronic Health Records (EHRs) with advanced functionalities have been shown to reduce medication errors and improve healthcare processes. EHRs are particularly valuable for infants and children as they support health surveillance, evaluation, and clinical decision-making. However, the development of such systems in emerging Asian economies, including the Philippines, remains limited.

While commercial health information systems are available in the Philippines, they present several challenges. Budget constraints, limited customization options, and cultural barriers complicate the adoption of these technologies. Additional drawbacks include reliance on external suppliers for updates and support, complexities in integrating with existing infrastructure, compliance with Department of Health (DOH) requirements, and increased demands for system maintenance and staff training to adapt to new workflows.

For routine childhood vaccinations to be effective, parents must ensure that their children receive the required doses according to the recommended schedule from birth until the age of one. Parents of eligible children under the DOH's routine immunization program can coordinate with Barangay Health Workers (BHWs) to receive the vaccination schedule. BHWs, in turn, diligently collect personal information from parents and record it in manual forms during immunization services.

Despite its importance, routine vaccination is not without its challenges. From the perspective of health workers, one of the primary challenges is ensuring vaccine supply chain management, including the availability and timely delivery of vaccine services, storage and handling requirements, and adequate training. Parents may also face issues related to access to vaccination services. Considering the inherent challenges, routine vaccines are still administered free of charge by the government in barangay health centers spread across the Philippines (Anderson, 2014).

In the specific context of Katangawan, a barangay in the city of General Santos, these challenges are particularly pertinent. According to the 2015 Census, the age group comprising infants, children, and adolescents aged 14 and below constitutes 34.08% (4,754) of the population (Philippine Statistics Authority, 2016). As the young population continues to grow in Barangay Katangawan, the local Health Center actively provides routine vaccines and serves the

community's needs. Immunization day is scheduled every Wednesday, with vaccinations administered monthly. However, the health center confronts challenges in accessing and updating children's immunization records due to their reliance on manual methods for record management. Currently, the health center collects child information from parents and stores records manually. Moreover, the health center struggles to determine vaccine availability and create accurate vaccination schedules due to the lack of proper documentation and real-time tracking of vaccine inventory.

To address pressing issues at the Barangay Katangawan Health Center, the researchers aim to develop a health information system that automates children's immunization schedules and manages vaccine inventory to enhance child public healthcare. The system aims to provide accurate and timely vaccinations, improve compliance, and optimize resource allocation for more effective disease prevention and healthcare management. It will assist health workers in managing children's records, providing individual immunization schedules for each child, and keeping track of vaccine inventory, which includes a Short Message Service (SMS) notification feature to inform parents about vaccine availability. Additionally, the system will generate periodic reports required by the Barangay Health Center administration and the Department of Health. It is designed with a modular and adaptable architecture, ensuring its compatibility for seamless integration into a future government electronic data repository. This flexibility allows for efficient data sharing, centralization, and collaboration across various government initiatives, enhancing the overall effectiveness and coherence of data management efforts.

Methods and Materials

Research Design

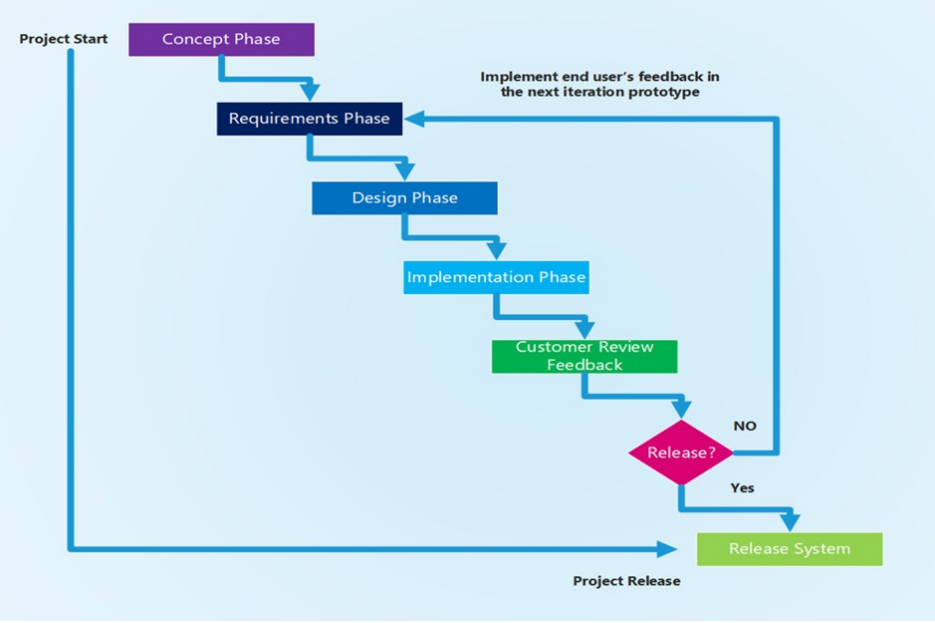
During the development of the community-based immunization management information system, the researchers were guided by the principles of design science research, emphasizing the creation of innovative solutions for real-world problems (Peffers et al., 2007; Hevner & Park, 2004). This approach is commonly employed in fields where the development of artifacts, particularly software systems, holds a central role (Hevner & Park, 2004). By integrating design science principles with the Evolutionary Prototyping Software Model, the methodology facilitated the systematic creation and refinement of software artifacts to meet the evolving needs of immunization management. This approach ensures a responsive solution tailored to the dynamic requirements of public health.

Evolutionary Prototyping Software Model

The developers employed the Evolutionary Prototyping Software Development Model to create

Figure 1

Evolutionary Prototyping Software Development Model



a web-based information system, starting with a conceptual phase, followed by the requirements, design, and implementation phases (Arnowitz et al., 2007). Subsequently, a customer review and feedback phase was conducted to accommodate modifications and include new features in later iterations, based on evolving requirements. These phases were repeated until the prototype was accepted, resulting in the final released system.

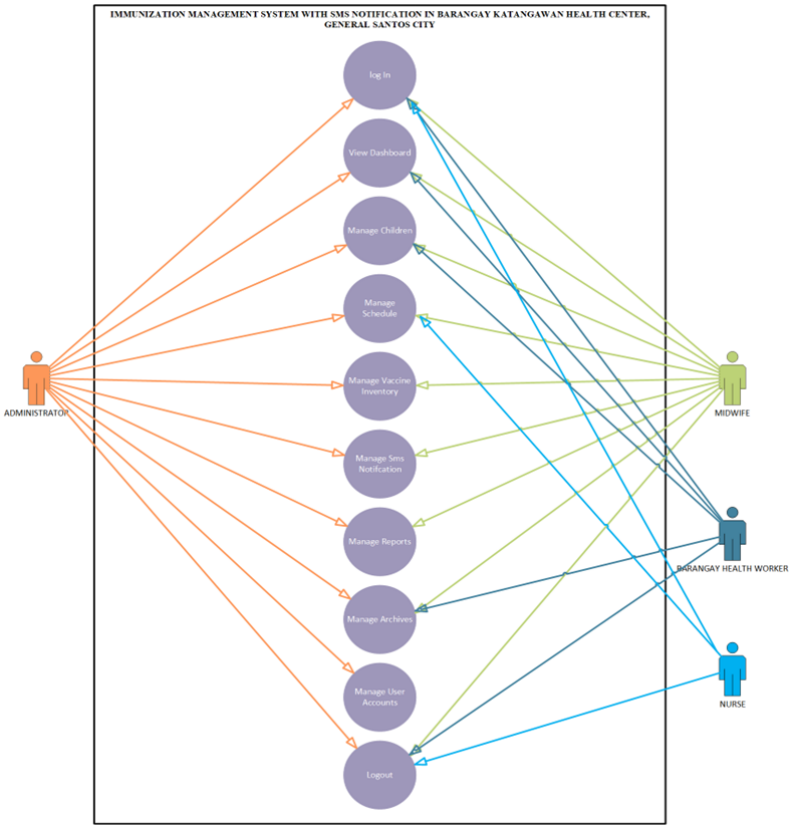
The project progressed through several key phases. In the concept phase, project initiation took place, involving problem identification and motivation, planning, team assignment, and the definition of the project's idea and feasibility. As the project transitioned into the requirements phase, the focus shifted to defining the objectives of the solution by documenting the software system requirements. This was achieved through user interviews, observations of the actual process, and a thorough review of related technologies and literature. To ensure alignment with government health guidelines, all data and interviews were sourced from government personnel and secondary data, utilizing existing forms and templates from the barangay health center.

The design phase created a system model and design based on user needs and evaluation (See Figure 2). The figure below illustrates the different use cases and activities for administrators, midwives, barangay health workers and nurses with the system. All users can access the system, including the dashboard. The administrator, midwife and barangay health worker can handle children's records. The administrator, midwife and nurse are responsible for managing immunization schedules. The Children's Archives can be managed by the administrator, midwife, and barangay health worker. The administrator and midwife can manage the vaccine inventory and SMS notifications. The administrator, midwife, and barangay health worker can view reports. Additionally, the administrator and midwife can export vaccine coverage reports to PDF/CSV. Only the administrator has the authority to manage user accounts.

The implementation phase converted the design into a functional system using PHP and MySQL for backend operations, and HTML, CSS, Bootstrap, and JavaScript for the user interface. Technologies such as Chart.js and DataTables were employed to create dynamic charts and enhance table interactivity, while an HTTP SMS API

Figure 2

Use Case Diagram for System Users



module enabled automated notifications.

The Customer Review and Feedback Phase involved user evaluation for functional and usability improvements, such as performance, ease of use, and compliance with the existing infrastructure. Feedback was collected from five users at the Barangay Health Center, categorized as midwives, nurses, and barangay health workers, during each iteration of system testing. Finally, the release phase marked the prototype's final testing and user approval before deployment. The final deployment of the system comes with an instruction manual or user guide that contains step-by-step instructions to guide users through the application's usage as well as potential troubleshooting steps if problems arise.

Unit of Analysis

The system was designed as the primary tool to manage and streamline immunization records, vaccine distribution, and local health activities in a selected Barangay within the city. It supports health workers, including midwives, nurses, Barangay Nutrition Scholars (BNS), and Barangay Health Workers (BHW), by providing functionalities that facilitate their roles in immunization efforts. The system's features and functionalities were developed based on the specific needs of these users, ensuring efficient access to and management of vaccine supplies.

Research Instruments

The research utilized a combination of interviews and document reviews to gather comprehensive data. Interviews were conducted to understand the challenges faced by health workers, assess the system's usability, and functionality, and identify potential areas for improvement. Additionally, existing documents, such as internal reports and data collection forms, were reviewed to gather insights and recommendations for system enhancements. To assess users' satisfaction and acceptance of the system, the researchers adapted the Unified Theory of Acceptance and Use of Technology (UTAUT) framework by Venkatesh et al. (2003).

Materials

The development of the system utilized a technology stack designed to meet the needs of barangay health workers. For backend operations, PHP was used to manage server-side logic, while MySQL handled database management, ensuring secure storage of records such as child profiles, vaccine data, and inventory information. The frontend was crafted using HTML, CSS, Bootstrap, and JavaScript to deliver a user-friendly interface. Additional tools included Chart.js, which was employed to create dynamic visualizations, and DataTables to enhance table interactivity. The system also incorporated an SMS notification module using the HTTP SMS API, which transformed an Android phone into an SMS Gateway for automated messaging. In terms of hardware, the system was designed to run on standard desktop or laptop computers with minimal specifications, including an Intel Core i3 processor or equivalent, 4 GB RAM, and 128 GB of free storage. It is compatible with Windows 10 or later operating systems and requires an internet connection for the admin to utilize the SMS notification feature. To assist barangay health center staff, a user guide was developed, providing step-by-step instructions and troubleshooting advice for effective system use.

Data Collection

Data for the development of the Immunization Management Information System (IMIS) were gathered from multiple sources. The study collected and reviewed data from various sources, including scientific papers, government websites, and other references related to Immunization Management Systems and other web -based technology applications. Additionally, interviews were conducted with key project stakeholders to gain insights into the current processes involved in immunization management. Direct observations were also made during immunization to provide a holistic understanding of the operational context.

Data Analysis

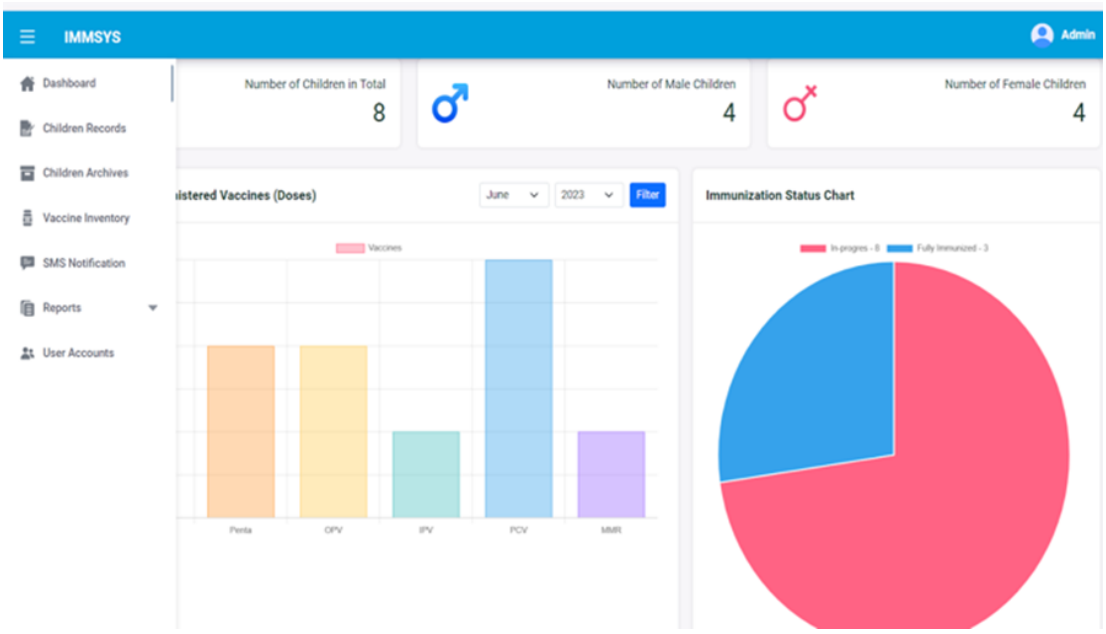
Data collected from interviews with barangay health center staff were analyzed by reviewing detailed notes from these discussions and observations of the immunization processes. Requirement analysis, user feedback, and iteration revealed three primary challenges: accessing patient records, monitoring vaccine supplies, and compiling accurate reports. The staff reported that the paper-based system resulted in disorganized records and delays in retrieving patient information. Manual tracking of vaccine inventory hindered the maintenance of real-time stock levels, and manual data entry for government reports increased the likelihood of errors. These challenges guided the development of the web application, which incorporates features such as a digital records system, inventory tracking, and automated report generation to improve efficiency and accuracy.

Data Privacy of Information System

Further, the system employs comprehensive measures designed to protect the

Figure 3

Dashboard of the Immunization Management Information System



confidentiality of sensitive health information in full compliance with the Data Privacy Act of 2012 (RA 10173) in the Philippines. The first line of defense against unauthorized access is using encryption techniques to convert data into secure codes. Additionally, strong, complex passwords with minimum length and character requirements are enforced for each user account. Role-based access controls (RBAC) ensure that only authorized personnel, based on their specific job responsibilities, have access to relevant data. Data segmentation further enhances privacy by minimizing data exposure and restricting access to only the information needed for each user's role.

Results and Discussion

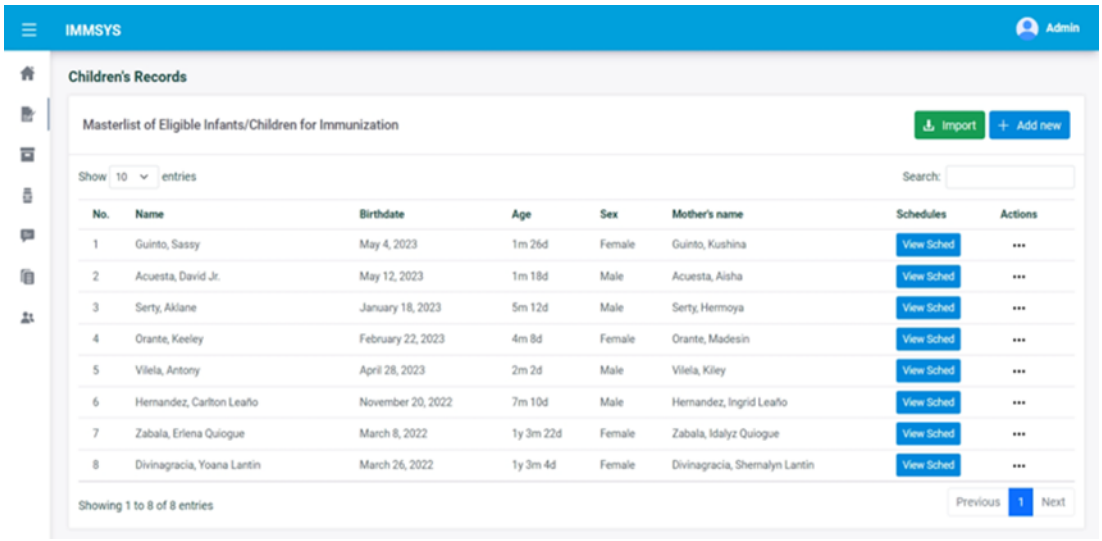
Following the two major software development iterations and based on positive evaluations from all users regarding the system's performance, effort expectancy, and facilitating conditions, the project has successfully achieved significant milestones and outcomes. This section delved into the core functionalities, encompassing the dashboard, children's records, immunization schedules, child archives, vaccine inventory, SMS notifications, reports, and user accounts. Additionally, it provides insights gained from this endeavor in pursuit of the identified objectives.

The system's dashboard shown above offers a visual representation of important information related to the administration of vaccines to children, as well as the demographic profile of infants and children. It provides an overview of the total number of children administered vaccines, statistics on immunization per purok, and information about the total number of children in records and archives. This not only provides snapshots of the vaccination program's overall progress but also provides barangay health workers, midwives and nurses with detailed, localized information that can guide decision-making and interventions. A report from the Asia-Pacific Economic Cooperation (APEC) underscores the importance of a dashboard to measure the progress of immunization programs and to be used to develop specific capacity-building initiatives (APEC Health Working Group, 2023). This aligns with initiatives from the Open Data Institute (Smith et al., 2017), highlighting that the purpose of the data dashboard is to transform intricate data into a coherent narrative, capturing attention, and guiding decision-making.

In Figure 4, users will have role-based access to perform various actions related to managing child records. This aligns with a previous study by Muscoplat and Rajamani (2017), emphasizing that users should be granted access based on their roles to consolidated immunization records for infants and children, client-specific clinical decision support for immunization, and

Figure 4

Children's Records

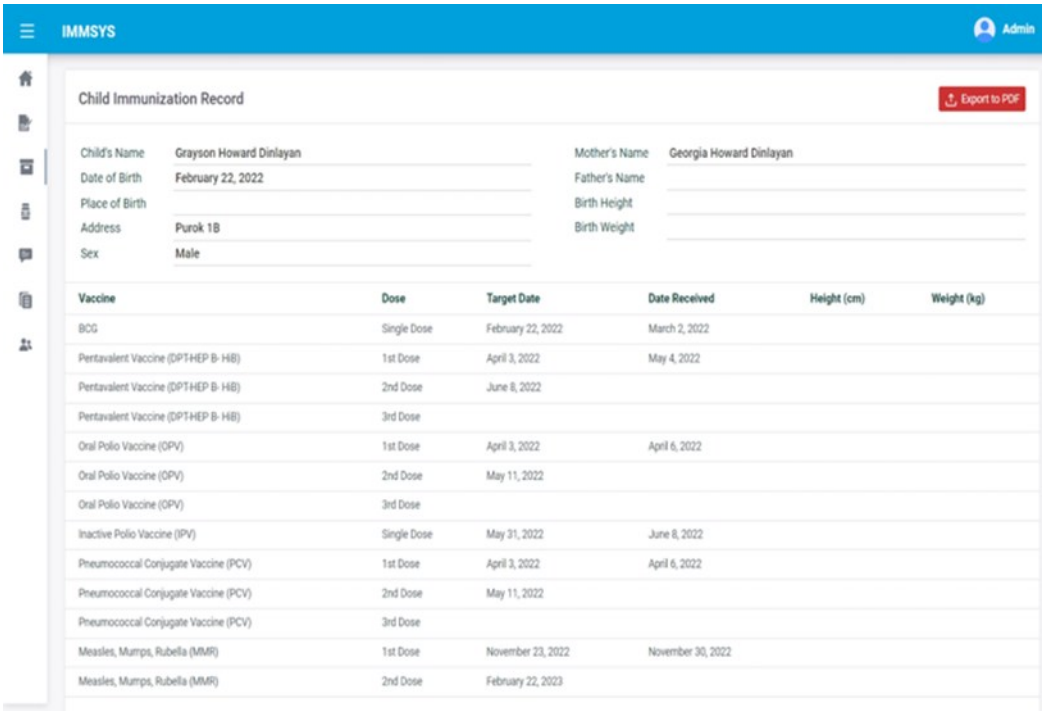


tools facilitating immunization assessment and outreach. Managing child records includes adding new child data to the system, accessing schedules for each child, viewing detailed information about the child, and updating child records. Additionally, the system allows users to archive child records when children have completed the immunization program, need to be transferred to another health center, or in the case of infant disease.

The figure below illustrates the immunization schedule for the selected child, which includes vaccine names, doses, dates,

Figure 5

Child Immunization Record Module



administering personnel, height and weight measurements. These data can be updated following the next scheduled vaccine if the child receives the intended vaccinations. This comprehensive record allows complete monitoring of a child's vaccination history and physical development. Notably, the system's flexibility enables data updates based on the next scheduled vaccine, ensuring the accuracy and relevance of the records. This functionality contributes to more effective and informed healthcare decision-making for the child's health by adhering to the immunization schedule consistent with demonstrated efficacy, safety, and feasibility (Committee on the Assessment of Studies of Health Outcomes Related to the Recommended Childhood Immunization Schedule, Board on Population Health and Public Health Practice, & Institute of Medicine, 2013).

Figure 6 displays the vaccine inventory page, providing authorized users access to comprehensive vaccine information, including available vials, lot numbers, expiration dates, and their status, which streamlines the tracking of vaccine supplies. The system allows users to add vials to specific vaccines as required, automatically allocating vials for vaccination based on their addition date, and concurrently initiating automated disposal of vials upon expiration. Furthermore, the system permits users to discard vials contaminated with impurities, ensuring the quality and safety of vaccine administration and promoting optimal healthcare management. Rebortera (2020) argued that it is crucial to manage inventory regularly, ensuring the consistent and timely delivery of vaccine supplies while adhering to quality standards. This is in support of the study of Okanda et al. (2016), which suggests a positive relationship between inventory management and the performance of the unit of vaccines and immunizations.

Figure 7 shows the new message page, which features an interface for sending SMS notifications. Intended users can verify the availability or unavailability of vaccines, which will determine the content of the message. The recipient list will automatically include all phone numbers of mothers stored in each child's record. Jong et al. (2021) asserted that addressing parents' forgetfulness regarding immunization could be achieved by incorporating text messaging and automation features into immunization information systems. Integrating these notification systems to suit the needs and preferences of target populations can enhance the effectiveness of immunization information systems. This involves updating delivery methods, offering awareness and educational information, and allowing flexibility in the local government unit of notification appointment scheduling (Tan et al., 2023).

The system provides users with two reports: the Vaccine Coverage Report and the Immunization Schedule Status Report, which can be exported in PDF and CSV formats. The Vaccine Coverage Report offers a comprehensive list of vaccines, along with details about vaccinated

Figure 6

Vaccine Inventory Module

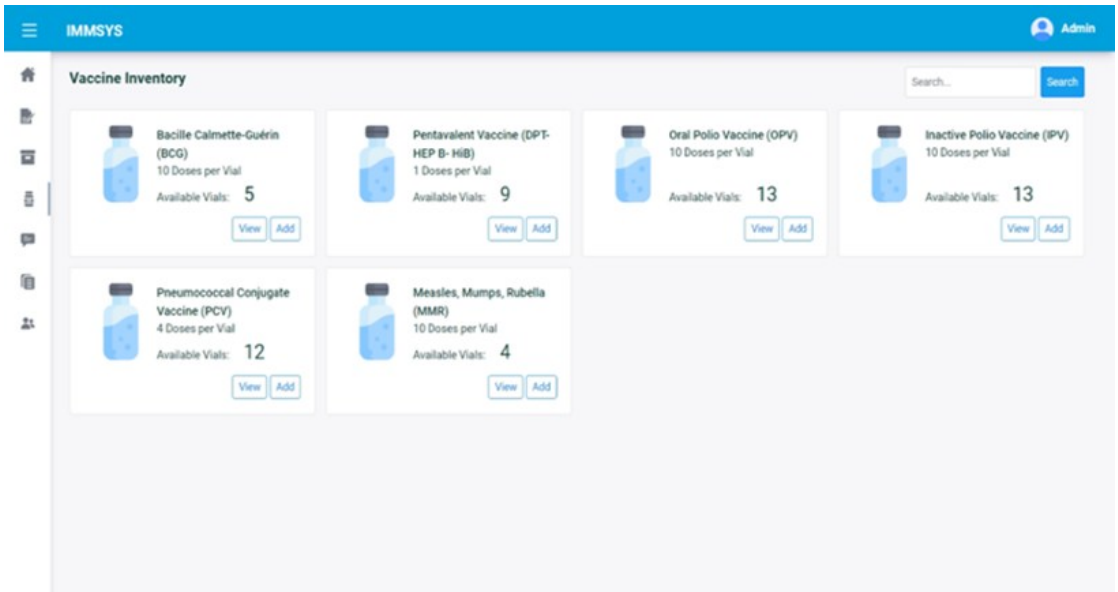
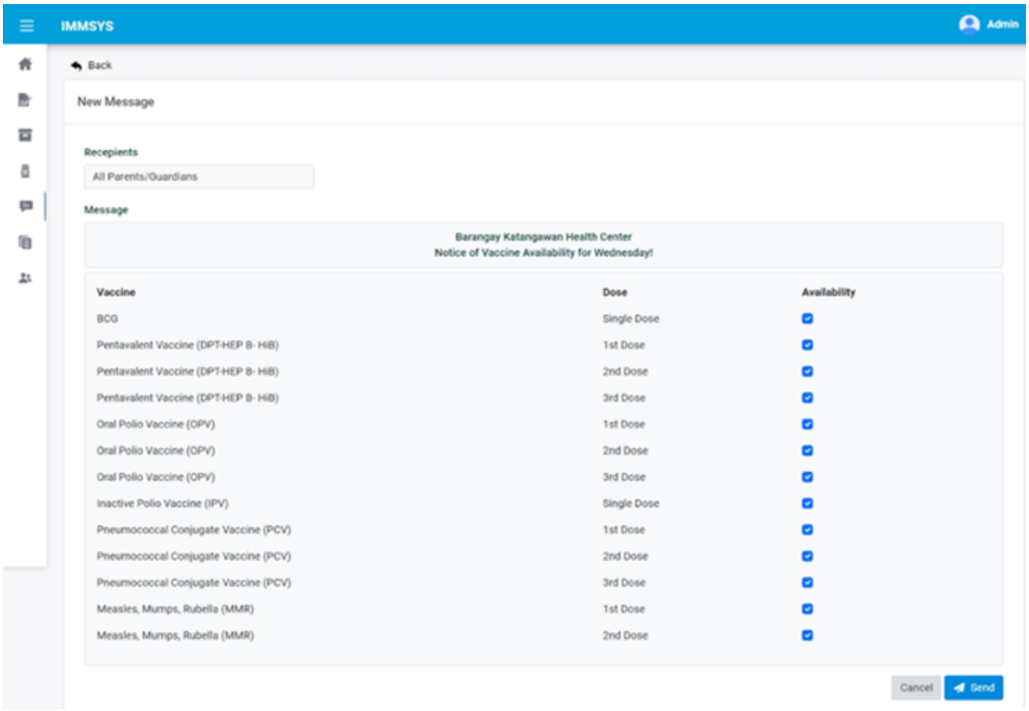


Figure 7

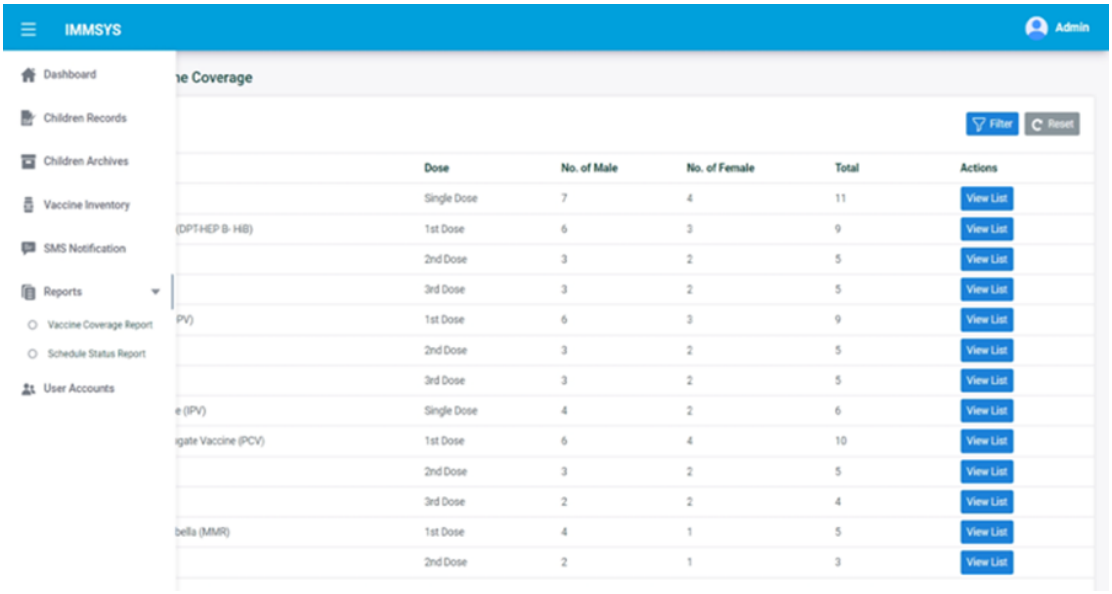
SMS Module



children, filterable by date, vaccine type, and dose. In contrast, the Immunization Schedule Status Report outlines each child's status, allowing updates to 'Overdue' or 'Upcoming' depending on whether the target date has passed or is approaching. These reports comply with the requirements of the Barangay Health Center and the Department of Health (DOH) as part of their reporting standards and regulatory requirements (DOH, 2021). Previous studies have highlighted

Figure 8

Reports



the importance of a robust reporting system, which serves both as a defaulter tracking mechanism to prevent missed immunizations and to ensure compliance with mandated reporting requirements for both children and adults (Kempe et al., 2017; Sulistyawati et al., 2023).

Conclusion, Implications and Future Research

Through extensive research and close collaboration with users, the system's design was carefully crafted to meet the specific requirements of midwives, barangay health workers and nurses, following the Evolutionary Prototyping Software Development Model. User feedback played a pivotal role in ensuring the usability and effectiveness of the system.

This paper outlines the features of a web-based Immunization Management System with SMS notifications implemented at the Barangay Katangawan Health Center in General Santos City. The system was developed to meet the specific requirements of the government's immunization program and to assist assigned barangay health workers in effectively managing children's records. It offers immunization schedules upon registering infants or children, monitors vaccine inventory, and enables midwives to send SMS notifications to parents about upcoming immunizations. Additionally, the system generates weekly and monthly reports that outline the total administered vaccines and list immunized children for each vaccine.

While this paper attempts to develop a comprehensive child immunization management information system, the results are constrained by the number of users and the specific research locale used by the researchers. Additionally, the testing of the information system is hindered by the limited availability of existing hardware and the network infrastructure in the barangay. However, these limitations create opportunities for future research and development. First, it is recommended to include an integrated prenatal and child immunization module that connects maternal prenatal information with children's immunization records for a comprehensive healthcare view. Second, a valuable addition is the inclusion of a smart reminder system that sends timely notifications via SMS or email to parents about upcoming immunization schedules, with alerts for missed or overdue appointments. Lastly, expanding the developed system to other barangays for usability and acceptability testing, involving diverse health workers for feedback, and enhancing the system's usability, adaptability, and effectiveness across different communities is suggested. If adopted by the 27 barangays of General Santos City in the future and seamlessly integrated with the City Health Office, with the necessary investments in ICT and network infrastructure, the proposed system will enhance immunization efforts through improved monitoring and coordination. These expansion and integration initiatives are designed to establish a standardized and centralized approach to immunization management. It seeks to foster collaboration among various health centers, ensuring a cohesive response to the city's immunization needs. Moreover, the integration with the City Health Office holds the promise of improving data accuracy, enabling comprehensive reporting, and supporting evidence-based decision-making. These enhancements will contribute to more effective public health strategies throughout the city.

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