Child Immunization E-Registry and SMS Reminder System Development in Nigeria

OLUMIDE OWOLABI[1], WINNIE HELEN DAVID[2], GRACE SIDI[3]
[1, 2] *University of Abuja*
[3] *Gombe State University*

Abstract- ***Routine Immunization (RI) coverage is low in Nigeria, despite efforts made by the Nigerian government and other immunization partners. The low coverage has been attributed to a lack of information on the health facility vaccination day, caregivers not recalling the date(s) of their child's vaccination date, and long waiting hours at the vaccination center. To improve immunization demand and uptake and data availability, we developed a web-based application that captures the child's data and sends SMS reminders to the parents on their child's immunization schedule. The study design, development, and implementation used an iterative human-centered (HCD) approach. We tested the system to evaluate performance and reach. The system was easy to use by the health providers, however, the data was insufficient to draw any conclusions on the impact.***

Indexed Terms- ***Human Centered Design, mHealth, Nigeria, Routine Immunization, SMS reminder***

I. INTRODUCTION

Routine Immunization (RI) coverage is low, with over 50% of unimmunized childrenin Nigeria[1],[2]. Most of these children are in poor and hard-to-reach communities where access to healthcare services is difficult. The low coverage has been attributed to a lack of information on the health facility vaccination day, caregivers not recalling the date(s) of their child's vaccination, and long waiting hours among others [4],[2],[3]. The traditional practice for vaccination reminders is via the child vaccination card, which contains the child's information, antigens to be taken, and the date of the next visit [6]. The child vaccination card is effective but may not be a good reminder as caregivers might misplace the cards or forget to check due to a tight work schedule and other daily routines [4]. Caregivers' low literacy also limits the use of immunization cards [3]. Therefore, there is a need for an effective communication system to increase child vaccination uptake and demand in Nigeria.

A reason for long waiting hours could be attributed to the time it takes the health workers to go pick up the vaccines from the storage facility and manually record children's information (name, date of birth, father and mother names, house address, and phone number) on the Child Immunization Register (CIR) and Immunization Card (IC) [4]. Other tools filled manually by the health workers include tally sheets and monthly immunization summary sheets which bring about data discrepancy.

Data error has also been a great challenge in the immunization space, especially in low-middle-income countries, as the administrative data at the health facility is either over *or* under-reported; there are also discrepancies between the administrative data and survey data [9],[7],[8].RI providers have been identified as the contributing factors to the RI data discrepancies, bringing about a lack of focus on the data quality, not understanding the effect of low data quality, and the high workload on RI providers [9].

To overcome these difficulties, the CIES reminder was established to eliminate the manual recording of child immunization information, improve data quality and increase immunization uptake and demand in Nigeria. CIES-reminder is mobile health (mHealth) technology that allows the health worker to register children (between 0-4 weeks old) in an e-registry and sends immunization SMS reminders to the parent's registered phone numbers on their child's immunization due date. The reminder messages are sent one day before the child's immunization due date.

Mobile health (mHealth) technology is a vital tool that has been unified into the healthcare delivery system for engaging and delivering health information to patients, as most people either own or have access to a mobile phone [10],[11]. Research has shown that there are over 5 billion mobile phone subscribers globally, and over 70% of them reside in low-and-middle-income countries including Nigeria [12]. Mobile phones can facilitate interactive and timely access to information via the call and text messaging (short message service (SMS)) feature [13]. SMS is widely used in sending and receiving messages and is supported by all mobile phones [11],[10],[13],[6],[15]. A single-page SMS has a length limit of 160 characters and can be delivered nationally or internationally within a short time [15].

mHealth has employed SMS for reminders, education, and monitoring of patients to improve access to healthcare services in different contexts [17],[16]. mHealth also supports healthcare workers' performance by disseminating clinical updates, learning materials, and reminders, especially in underserved rural areas in low-and middle-income countries [16]. In Ethiopia, an SMS reminder system was developed to improve RI programs in the North-West of Ethiopia. The system was tested among 30 participants, and all the text messages were successfully delivered to participants from the automated system [13]. An automated SMS distribution system for sending reminders was also developed in Kenya to collect, aggregate and display health information. The system had an SMS data collection tool for sending and receiving structured messages and an analytic tool for data visualization and analysis. The system was tested in Nairobi among 20 caregivers; however, the study's evidence was insufficient to prove that SMS reminders improved attendance at healthcare appointments [19].

Similarly, an SMS-based system was developed in India to improve vaccine uptake and compliance in childhood immunization programs [19]. Abia State Government partnered with William Coley Hub Africa in 2018, to launch an automated reminder technology called "Remind me" in the state capital - Umuahia. The reminder technology sent text messages to mothers to remind them of their child's immunization schedule and the closest facility where they can assess the service [20]. An Immunization Reminder &Information SMS System (IRISS) was developed and piloted in Kebbi State in Nigeria; to improve RI demand and reduce the left-out and dropout rate of the RI program. The system used SMS to inform and educate community members about the importance of immunization andremind caregivers about their child's immunization and health facility schedules [14]. Both studies demonstrated that the use of SMS-based systems is effective in improving healthcare access and service delivery.

This paper describes the development of the CIES-reminder system and its effectiveness in capturing children's immunization information and sending SMS reminders to their parents.

II. METHODOLOGY

The CIES-reminder was developed using the human-centered design (HCD) approach because it follows the software development life cycle iteratively. With this approach, we designed the system with the end-user and revise it at any point of development to meet the user's needs.

Reference [22] defined HCD as "the mandatory upstream process that enables a design team to incorporate human requirements into the design of a system", and reference [23] described HCD as "a creative approach to problem-solving that involves the end-user from the very beginning and places them at the center of the digital design process". HCD has been widely applied in healthcare and other industries in designing interventions to the target population's needs and contexts. We used the HCD approach to design the CIES-reminder application through the core three phases of HCD – inspiration, ideation, and implementation explained in table 1.

Table 1: Human-Centered Design Phases

S/N	HCD Phases	Description
1	Inspiration	The inspiration phase involves learning directly from the people you are designing for as you

		immerse yourself in their lives and intensely understand their needs.
2	Ideation	This is a phase where we put together what we've learned at the inspiration phase; identify opportunities for design, and prototype possible solutions.
3	Implementation	In the implementation phase, our solution is brought to life, and eventually, to the market. At this point, we can also tell that our solution will be successful because the people we are looking to serve were involved in the process

A. Inspiration phase

We conducted a desk review, consulted, and observed/immersed ourselves with caregivers and RI providers at the health facility to understand the challenges they faced during immunization. A letter was provided from the University of Abuja's Post Graduate school to the management of the Kuje Primary Health Care requesting that we should be granted permission and given the necessary support needed to pilot the study at their hospital.

B. Ideation phase

We collated findings from the inspiration phase to define the scope of our study and designed the prototype. The CIES-reminder system has 5 main components – SMS integration, data capturing/management, messaging, reporting, and user roles as depicted in figure 1.

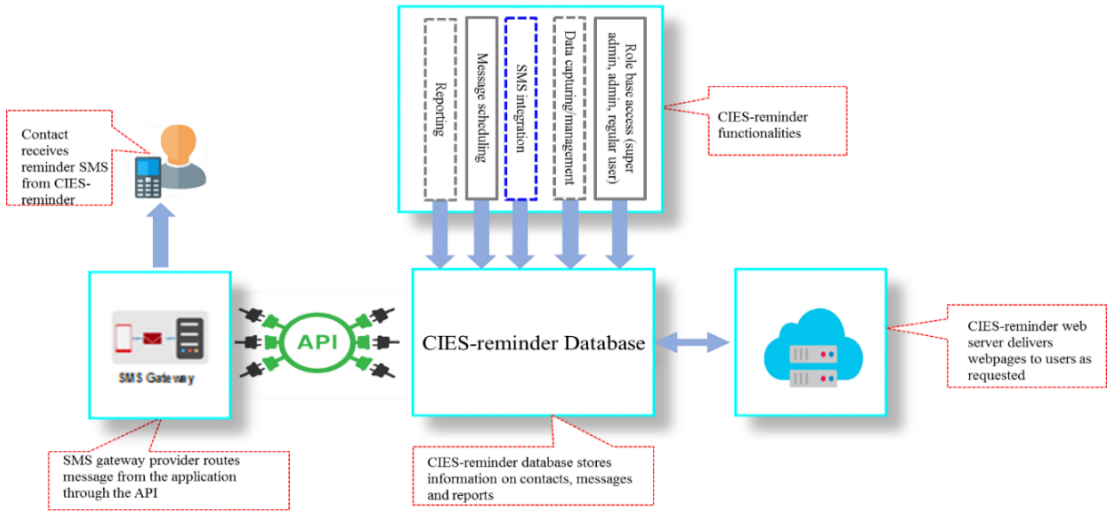

Figure 1: CIES-reminder architectural design

C. Implementation phase

CIES-reminder is a web-based application, developed using a hypertext pre-processor (PHP) language – a widely used open-sourced scripting language for web development. To ensure automated messages are delivered from the CIES-reminder application to recipients, the system was integrated into an Ebulk SMS (SMS provider) gateway using an Application Program Interface (API).A login page was developed for the users to provide their username and password for authentication before accessing the system. Upon successful login, the user is redirected to the dashboard where they can access the dashboard. The dashboard shows the summary of children registered, the main and submenus. There are three categories of users to the application, the admin, Routine Immunization (RI) provider, and program manager. The admin can perform all tasks on the system, the RI provider can perform all tasks except registering a facility and user while the program managers can only view and download reports.

The main menu on the system includes Children, Vaccines, Hospitals, Analysis, and Users. Three out

of the main menus have submenus for easy navigation: Children (register a child and registered children), Vaccinate (vaccinate a child and vaccinated children), and Users (register a user and registered users) as shown in figure 2.

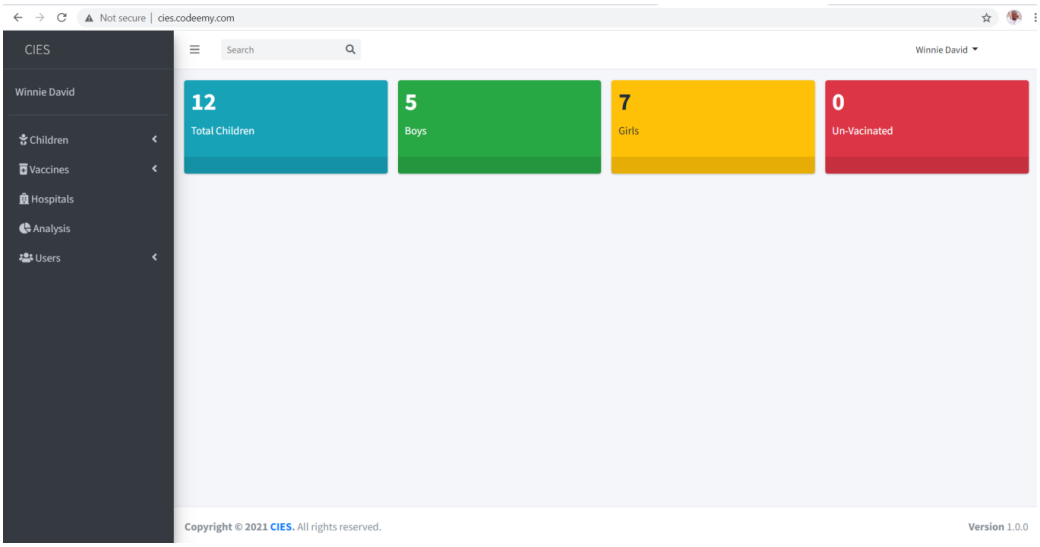

Figure 2: Dashboard showing the system's main menu

The system was developed to query the child table daily and the list of children who were due for vaccination is extracted, an SMS reminder was sent to the phone numbers of the children's parents as provided during registration. The field queried was the date of birth which was matched to the vaccination dates registered on the system. The vaccination dates are automatically assigned to the list of antigens on the database. For example, OPV 1, Penta 1, and PCV 1 are given at 4 weeks. Thus, the system queries children who were 4 weeks old and sends an SMS reminder. The system also matches the child's information to the hospital he was registered under, extracts and adds the hospital name to the text message sent to enable the parent to know the hospital to take their child for immunization. With the hospital name on the message, it makes it also easier for the parent to identify the source of the message. The healthcare provider can update the vaccination status of each child on the system after the child has been vaccinated. A list of reports is generated from the system and is downloadable, copied, or printed for decision-making.

II. RESULTS

The system was tested with 12 children whose parents consented to take part in the study. 42% of the children registered on the system were males while 58% were females. Among the children registered, the distribution of children given birth in April, May, June, and July 2021 were 3 each. No registered child was given birth before April or after July 2021. Only 25% of the children were registered on the day/date of their first hospital visit for BCG, OPV 0, and HepB 0 while 75% were registered after they had taken either Penta 1 or Penta 2 during their second or third immunization visits respectively as seen in figure 3.

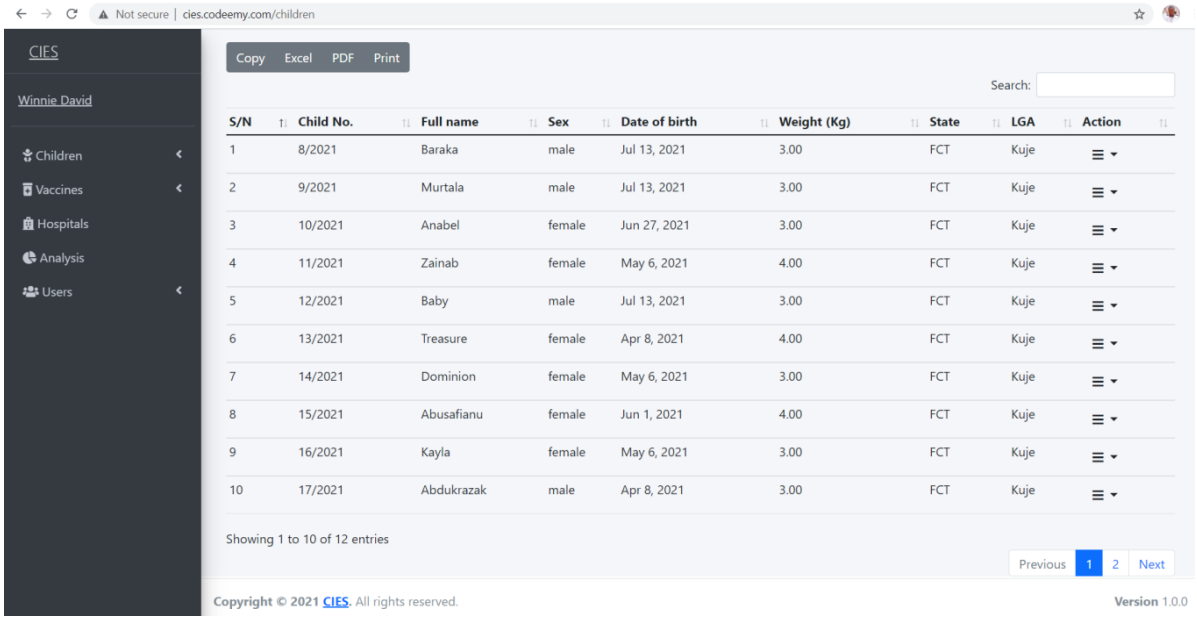

Figure 3: Registered children's table

In terms of SMS reminders, 46% of registered phone numbers received SMS reminders from the CIES-reminder system. This implies that parents who did not receive the SMS reminder may not remember to take their children for vaccination on the due date. To evaluate the system performance and validate the data reported on the system, we interviewed the parents whose messages were shown delivered from our system and they confirmed receiving the SMS reminder. Parents who received the SMS visited the facility upon receiving the reminder, and their immunization status was updated after vaccination. However, the data is insufficient to draw any conclusions.

III. DISCUSSIONS

Africa, including Nigeria (with approximately a 180 million population) has the largest and fastest-growing number of mobile users globally; 71% of the Nigerian population uses mobile phones as their primary means of communication [24]. The CIES reminder leveraged this means of communication to send SMS reminders to parents in Kuje PHC in FCT about their child's vaccination schedules. To ensure that registration was easier and more seamless, we designed the system to allow registrations to be conducted by health workers. This strategy was proven effective in a similar study conducted in Ethiopia [13].To prevent unwanted persons from accessing the system, a login page that allows the user to provide their username and password for authentication was provided and different users were assigned different roles within the system– a strategy that has been adopted by similar innovations to ensure system information security [13],[19].

The system was tested among 12 children who were successfully registered into the CIES-reminder, and SMS reminders were sent to their caregivers. Only 46% of these messages were delivered, a phone interview was conducted and we found that participants whose messages were delivered on our system received our message; caregivers whose messages were undelivered did not receive the message. The reasons for non-delivery could be attributed to poor network coverage or phone switching off, a major barrier found in similar SMS interventions [13],[19]. The evidence from our study was insufficient to draw any conclusion, a similar report from a study conducted in Kenya and tested in Nairobi among 20 caregivers; the study's evidence was insufficient to prove its impact [19].

CONCLUSION

The development of the CIES-reminder system was an iterative process that needed to be carefully developed and tested to ensure it meets the user requirements. The application was developed to send SMS reminders to caregivers about their child's immunization due date. The system was designed for easy manipulation and had an integration feature of accessible communication with other systems. We were faced with the challenge of low participation. Also, we had a less than 50% SMS delivery rate when tested. In developing similar innovation, the system should be designed to send SMS reminders to fathers and other phone numbers if provided during registration, with this if the SMS to the first phone number fails the other will be delivered especially where the phone numbers are registered on the different mobile network providers.

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REFERENCES

[1] Antai, D. (2009). Inequitable childhood immunization uptake in Nigeria: a multilevel analysisof individual and contextual determinants.*BMC infectious diseases*, *9*(1), 1-10.

[2] National Population Commission (NPC) [Nigeria] and ICF. (2019). Nigeria Demographic and Health Survey (2018). Abuja, Nigeria, and Rockville, Maryland, USA: NPC and ICF.

[3] Obi-Jeff, C., Rakhshani, N. S., Bello-Malabu, J. I., Nwangwu, C., Nwaononiwu, E., Eboreime, E., &Wonodi, C. (2020). Vaccine indicator and reminder band to improve demand for vaccination in Northern Nigeria: A qualitative evaluation of implementation outcomes. *Vaccine*, *38*(26), 4191-4199.

[4] Abdulraheem, I. S., Onajole, A. T., Jimoh, A. A. G., & Oladipo, A. R. (2011). Reasons for incomplete vaccination and factors for missed opportunities among rural Nigerian children. *Journal of Public Health and Epidemiology*, *3*(4), 194-203.

[5] Abbas, A. H., & Yusof, Y. (November 2011).Children's vaccination reminder via SMS alert.In 2011 International Conference on Research and Innovation in Information Systems (pp. 1-5). IEEE.

[6] Ibraheem, R. M., & Akintola, M. A. (2017). Acceptability of reminders for immunization appointments via mobile devices by mothers in Ilorin, Nigeria: a cross-sectional study. *Oman medical journal*, *32*(6), 471.

[7] Baguune, B., Ndago, J. A., &Adokiya, M. N. (2017). Immunization dropout rate and data quality among children 12–23 months of age in Ghana. *Archives of Public Health*, *75*(1), 1-8.

[8] Dunkle, S. E., Wallace, A. S., MacNeil, A., Mustafa, M., Gasasira, A., Ali, D., ... & Sandhu, H. S. (2011). Limitations of using administratively reported immunization data for monitoring routine immunization system performance in Nigeria. 2014. *The Journal of infectious diseases*, *210*(suppl_1), S523-S530.

[9] Omoleke, S. A., & Tadesse, M. G. (2017). A pilot study of routine immunization data quality in Bunza Local Government area: causes and possible remedies. *The Pan African Medical Journal*, *27*.

[10] Schnall, R., Rojas, M., Bakken, S., Brown, W., Carballo-Dieguez, A., Carry, M., ... & Travers, J. (2016). A user-centered model for designing consumer mobile health (mHealth) applications (apps).*Journal of biomedical informatics*, *60*, 243-251.

[11] Gurman, T. A., Rubin, S. E., & Roess, A. A. (2012). Effectiveness of mHealth behavior change communication interventions in developing countries: a systematic review of the literature. *Journal of health communication*, *17*(sup1), 82-104.

[12] World Health Organization (2011). mHealth New horizons for health through mobile technologies. Available from: https://www.who.int/goe/publications/goe_mhealth_web.pdf/. [Accessed August 2021]

[13] Mekonnen, Z. A., Hussien, F. N., Tilahun, B., Gelaye, K. A., & Mamuye, A. (2019). Development of an automated text-message reminder system to improve the uptake of child vaccination in Ethiopia. *Online journal of public health informatics*, *11*(2).

[14] Direct Consulting and Logistics (2011). Evaluating SMS messaging for immunization demand generation in Nigeria: Immunization Reminder and Information SMS System (IRISS). Available from: https://dclnigeria.com/wp-content/uploads/2021/04/IRISS-updated-technical-brief.pdf/. [Accessed August 2021]

[15] Chan, K. C., & Tien, D. A. (2013). multi-tenant platform for SMS-integrated services. *International Journal of Computer Networks & Communications*, *5*(6), 205.

[16] Amoakoh-Coleman, M., Borgstein, A. B. J., Sondaal, S. F., Grobbee, D. E., Miltenburg, A. S., Verwijs, M., ... & Klipstein-Grobusch, K. (2016). Effectiveness of mHealth interventions targeting health care workers to improve pregnancy outcomes in low-and middle-income countries: a systematic review. *Journal of medical Internet research*, *18*(8), e5533.

[17] Hamine, S., Gerth-Guyette, E., Faulx, D., Green, B. B., & Ginsburg, A. S. (2015). Impact of mHealth chronic disease management on treatment adherence and patient outcomes: a systematic review. *Journal of medical Internet research*, *17*(2), e3951.

[18] Pejaver, R.K., (2020). G447 (P) IAP immunize India: SMS text-based vaccination reminder service program–an innovation.

[19] Githinji, S., Jones, C., Malinga, J., Snow, R. W., Talisuna, A., & Zurovac, D. (2015). Development of a text-messaging intervention to improve treatment adherence and post-treatment review of children with uncomplicated malaria in western Kenya. *Malaria Journal*, *14*(1), 1-9.

[20] Nigerian Health Watch (2011). Remind Me: A tech solution to improve immunization coverage in Nigeria. Available from: https://nigeriahealthwatch.com/remind-me-a-tech-solution-to-improve-immunisation-coverage-in-nigeria/.[Accessed August 2021]

[21] Forenbacher, I., Husnjak, S., Cvitić, I., & Jovović, I. Determinants of mobile phone ownership in Nigeria. 2019. *Telecommunications Policy*, *43*(7), 101812.

[22] Guy André Boy (2011). Introduction: A human-centered design approach. Available from: https://www.cambridge.org/core/services/aop-cambridge-core/content/view/F726100E2E7D0C825CB526FD7412C48E/S2053470117000087a.pdf/human centered_design_of_complex_systems_an_experiencebased_approach.pdf /[Accessed September 2021]

[23] Miklos Philips. The Importance of Human-centered Design in Product Design. https://www.toptal.com/designers/ux/human-centered-design/[Accessed September 2021]

[24] Forenbacher, I., Husnjak, S., Cvitić, I., & Jovović, I. (2019). Determinants of mobile phone ownership in Nigeria. 2019. Telecommunications Policy, 43(7), 101812.