

Usability and acceptability of electronic immunization registry (EIR) data-entry workflows from the
healthcare worker perspective in Siaya, Kenya

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Abstract

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Global Health

Introduction: Digital health tools such as electronic immunization registries (EIRs) have the potential to improve patient care and alleviate challenges that arise from the use of paper-based clinic records for reporting. To address some of these challenges, the Kenya Ministry of Health (MOH) and the International Training and Education Centre for Health in Kenya (I-TECH-Kenya) implemented an EIR system in all 161 of Siaya county's immunizing clinics between 2018 – 2019. Successful implementation of digital health tools depends on many factors, one of which is alignment between the technology and the context in which it is used. One important aspect of that implementation context is the perceptions of the healthcare workers (HCWs) using the EIR. Without full adoption of the EIR by HCWs into their clinic workflow, many of the potential benefits of the EIR cannot be realized. This study evaluates HCW perceptions of usability and acceptability of multiple clinic workflows using the new EIR.

Methods: We performed a mixed-methods pre-post study using semi-structured interviews of healthcare workers at 6 facilities in Gem sub-county of Siaya county, Kenya. We interviewed HCWs at each facility 4 times: at baseline and once after implementation of each of three different workflow modifications

(n=24 interviews). The interviews used a combination of open-ended interview questions and scale-based indicators based on the NASA Task Load Index and usability heuristics. The baseline state involved dual data-entry with paper records and the EIR. We implemented the three workflow modifications for one full day each: fully paperless data entry, preparation of an appointment diary prior to the day's patient visits began, and a combination of paperless plus preparation workflows together. We compared aggregate scores from the indicators and interview themes across each of the four workflows in order to understand changes in usability and acceptability of the EIR.

Results: We found that, overall, the EIR clinic workflows were considered usable and acceptable by the HCWs. Of the modified workflows, we found the HCWs perceived the fully paperless workflow to be the most favorable, while the baseline, preparation, and combined workflows had mixed results. In all workflows, benefits perceived by the HCWs included ease of clinical decision-making using the EIR, reduced mental burden of the data entry when using the EIR, and ease of identification of errors.

Challenges perceived by the HCWs regarding workflow acceptability included contextual challenges such as staffing shortages and lack of network connectivity, EIR platform challenges such as errors saving records and missing fields, and workflow challenges such as the dual data entry burden of paper and digital tools.

Conclusion: Fully paperless EIR implementation shows great promise from a workflow acceptability standpoint, contingent upon presence of supporting contextual clinic factors and resolution of system performance and design challenges. An acceptable EIR will provide adequate flexibility for HCWs to implement the new system in their unique clinic context. Rather than trying to identify a singular best workflow, future efforts to optimize EIR implementation should look for ways to maximize flexibility, reliability of the app, and strong enabling environments, and let the HCWs in each clinic match the EIR to their real-world context to have the best results for data use.

Keywords: workflow; digital health; electronic immunization registry; acceptability; healthcare worker

Abstract

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Introduction

Vaccines remain one of the most safe and cost-effective public health interventions for reducing morbidity and mortality worldwide: every year, vaccines prevent 2-3 million deaths globally (1, 2). An additional 1.5 million deaths can be avoided if children are fully immunized; in 2018, 19.4 million infants globally did not receive any vaccinations (3). Since 2007, Kenya has consistently exceeded the Universal Child Immunization goals of at least 80% of children receiving the third dose of DTP vaccine (DTP3) (4). However, the rate of DTP3 vaccination varies widely by geography: less than half of Kenya's 286 sub-counties reported DTP3 coverage greater than 80% in 2013 (5, 6), with utilization of immunization services being lower amongst the poor, less educated, and those living in urban informal settlements (6). Nationally, an estimated 450,000 children are not fully vaccinated in Kenya (5). Immunization services in Kenya are delivered through a network of more than 12,000 health facilities and clinics throughout the 47 counties in the country (7). County governments are responsible for provision of health services including the generation and reporting of information on immunization services and immunization coverage reached (5).

To address the health burden of vaccine-preventable diseases Kenya established their Expanded Programme on Immunisation (EPI) in 1980, aligning with the World Health Organization's global EPI program. Kenya's EPI reporting relies on a primarily paper-based reporting system to manage the immunization data collected from these 12,000+ health facilities on a monthly basis. This reporting procedure is a manual process based on paper-based record-keeping across as many as seven different paper tools at each facility, including the Mother and Child Health Booklets, immunization tally sheets, and Immunization Permanent Register, among others. According to the Kenya Ministry of Health's comprehensive Multi-Year Plan 2015 – 2020, "The counties face several challenges in their ability to critically analyze the immunization data reported and developed at the county and using the information in development of plans based on this information" (5). Addressing challenges such as these by building capacity of frontline health workers, strengthening infrastructure and logistics, and strengthening

monitoring and surveillance systems are key components of several global strategies and national action plans, including the Global Vaccine Action Plan and the Kenya Ministry of Health (MOH) Comprehensive Multi-year Plan for Immunization (8-10).

To mitigate immunization reporting and surveillance challenges stemming from this reliance on multiple paper-based tools, the International Training and Education Centre for Health in Kenya (I-TECH-Kenya), affiliated with the University of Washington, partnered with the Kenya MOH to digitize immunization records in one pilot county: Siaya county in western Kenya. I-TECH and the MOH developed an electronic immunization registry (EIR) which can manage electronic vaccine records from multiple health facilities and is adapted from the OpenSRP/OpenMRS open source platform (11, 12). The EIR, called the Kenya Immunisation Platform (KIP), is a tablet-based platform that allows health care workers (HCWs) to register children, quickly record vaccines administered, identify children defaulting on vaccinations, and generate aggregate facility reports. After the successful pilot phase in 20 facilities of Gem sub-county, the EIR was implemented in all 161 immunizing clinics in Siaya county between 2018 - 2019.

Digital health tools such as EIRs can support healthcare workers in increasing the safety and quality of care (13). The use of EIRs specifically shows promising results in increasing vaccination uptake, adherence, and timeliness (14, 15). However, health informatics technologies can also be disruptive (16) and have unintended consequences including additional workload, over-weighted trust in the technology, communication routine interruption, and medical errors if there is a mismatch between the system and the real-world practices of the healthcare context in which it is implemented (16, 17). The benefits that EIRs promise can only be realized if they are successfully adopted and integrated into existing patient care processes. Many digital health implementations have failed to be implemented at-scale in part due to incorrect assumptions about behaviors and preferences of the users of the technology—in the case of EIRs, the HCWs (18, 19). Additional research is needed to understand the benefits and barriers of EIR implementation and what can be done to mitigate such barriers (20, 21), including regarding workload and system usability which are at the intersection of task and worker elements (22).

This study is part of a comprehensive evaluation of the implementation of the EIR in Siaya county, including a baseline usability study and time-in-motion study. The portion of the evaluation reported here assesses point-of-care workflows using the EIR from the perspectives of the HCWs who are using the system. The aim of this study was to understand healthcare worker attitudes and perceptions of the usability and acceptability of different clinic workflows using the EIR. When redesigning work, implementers should consider different elements of a work system including the individual, the tasks, the tools and technologies, the physical environment, and the organizational conditions (23). The goal of this study was to provide insight into the features of the workflow which were a good match between the system and reality and were considered acceptable by the HCWs, and which aspects of the technology's integration into the workflow should be improved before the EIR can be implemented in other counties throughout Kenya. By identifying factors positively and negatively affecting usability and acceptability of the EIR, our research sought to inform strategies to improve EIR adoption and consequently data quality, data demand, and data use in MOH efforts to improve national vaccination coverage (8).

Methods

Conceptual Framework for Study

Technology adoption in a clinical environment depends on many factors which can all vary from system to system and user to user. One useful framework summarizing these factors is the FITT ("Fit between Individuals, Task and Technology") framework which proposes that technology adoption depends on the fit between the attributes of the individual, attributes of the technology, and attributes of the clinical tasks and processes (as shown in Figure 1 below) (24, 25).

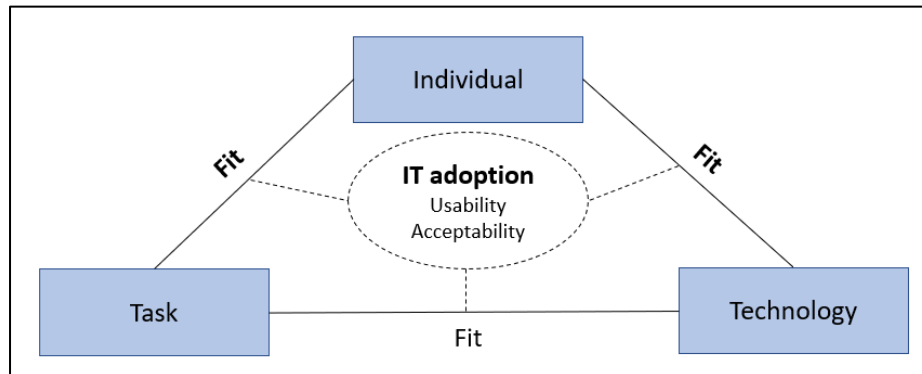


Figure 1: Modified FITT Framework: IT-adoption depends on the fit between individual, task and technology. In the context of our study, since adoption of the EIR was mandatory, we will evaluate the usability and acceptability of the EIR within the clinic workflows in place of this construct.

In the context of our study, the technology (the EIR) was implemented throughout all facilities in a top-down approach. Since “adoption” of the technology we implemented is then mandatory, rather than evaluating the degree of technology adoption, we instead evaluated the success of that adoption by adapting our outcome of interest to instead be usability and acceptability of the EIR’s integration into different clinic workflows.

A workflow is the “sequence of physical and mental tasks performed by various people within and between work environments” and it can occur sequentially or simultaneously, as well as at several levels from within a single person to across entire organizations (26). The workflow we specifically assessed was the sequence of data-entry actions taken by a healthcare worker within an immunization clinic.

Study Design

We used a mixed-methods approach to assess how modifications made to the immunization clinic workflow amongst facilities using EIRs affected healthcare worker perceptions of usability and acceptability of the EIR based on these frameworks. We assessed perceptions using semi-structured key informant interviews both before and after carrying out three modifications to the clinic workflow. The semi-structured interviews had both quantitative measures, described below, and open-ended interview questions.

We conducted a pre-post study to examine three different workflow modifications and their effect on usability and acceptability of the EIR workflow. During the first week of the study, we conducted baseline clinic observations and interviews. In the second week, we implemented modifications to the clinic workflows and evaluated changes in healthcare worker interview responses.

Intervention: Workflow Modifications to Optimize KIP Implementation

Table 1 describes the three specific interventions which we chose and rationale behind piloting them.

Table 1: Workflow Modifications and Rationale

Workflow	Description of Workflow Modifications	Anticipated Benefits
Baseline	The existing workflow in the immunization clinics consisted of dual data entry in both paper registers and the EIR at the same time during each immunization session. Upon initial introduction of the EIR, facilities were not instructed to adopt any workflow specifically, but rather each facility integrated the EIR into their clinic activities organically.	Not applicable
Preparation	Before the immunization clinic starts seeing children in the morning, the HCW prepares the list of expected appointments for the day using the paper registers. Then the HCW confirms that each expected child is entered in the EIR and their information is up to date. The immunization clinic visits then proceed as normal.	Inconsistencies between paper and EIR records are identified prior to the session and completed in a batch for all expected children rather than being identified and corrected while the mother-child pair is present and waiting. We expect this to save time and thereby improve usability and acceptability of the EIR.
Paperless	HCWs remove the steps involving paper records during the immunization visit sessions. Instead, only the EIR is used during the session. Note that it is still official policy to record information in the paper register, so under this modified workflow the paper entry will take place all at once after all immunization sessions are completed	By removing the dual data entry aspect of the baseline workflow, we expect that use of the EIR will be perceived as being less complicated, involving less time pressure, and broadly be more acceptable and usable as defined by our two guiding frameworks.
Combined Preparation and Paperless	HCWs implement the preparation and paperless workflows in the same day. That is, appointment lists are prepared in the morning and the clinic workflow proceeds without paper records for the day (only the EIR)	Benefits, challenges, and interactions of the two workflows are jointly assessed

We implemented each workflow for a one-day period. The “preparation” workflow was implemented on the first day, then “paperless” on the second day, and the third day “preparation” and “paperless” workflow modifications were both implemented to understand their joint benefits and challenges. Implementation of the workflows consisted of a training of the healthcare worker at the beginning of the day wherein the data collector talked through what the workflow modification is and required changes to the workflow. Then, immunization visits and observations took place as they did during baseline, except with the modified workflow in place. These same steps to implement the modified workflows took place at all six facilities, with one data collector assigned to each facility for the week and working with the same healthcare worker.

Study Setting and Facility Sampling

There are 161 immunizing facilities in Siaya county and the EIR was implemented in all of them over a two-year period. The EIR was first implemented in 20 facilities in Gem sub-county of Siaya county which was chosen because the program has the most experience working with the ministry of health and facility staff in these counties, which simplified the data collection and logistics process. From among these facilities, we sampled 6 public facilities of different sizes (small versus large, based on the size of the facility catchment area) in order to explore possible differences in acceptability and usability by clinic size. We limited our data collection to facilities who have been using the EIR for more than three months in order to ensure the application has been fully adopted by each facility. Specifically, the included facilities were:

Table 2: Facilities selected for workflow modification in Gem sub-county

Facility	Facility Type	Facility Size
Facility A	Level 2: Dispensary	Small facility
Facility B	Level 2: Dispensary	Small facility
Facility C	Level 3: Health center	Large facility
Facility D	Level 3: Health center	Large facility
Facility E	Level 3: Health center	Large facility
Facility F	Level 4: County referral hospital	Large facility

Each selected facility had one tablet with the EIR application installed on it. Some facilities had only one healthcare worker using the EIR while others had multiple who used it. At each facility, interview informants were selected based on which healthcare worker was on duty and using the EIR during the two-week data collection period. We interviewed one healthcare worker from each of the six facilities and for each healthcare worker conducted four interviews: one at baseline and one after each workflow modification (preparation, paperless, and preparation plus paperless) was implemented. Thus, in total we conducted 24 interviews representing usability and acceptability of four workflows from six healthcare workers (in six different facilities). Though six individuals is a small sample size for most statistical tests, it is generally considered acceptable for usability testing and heuristic evaluation (27).

Measures of Interest

Usability and acceptability have been defined as distinct concepts. Sekhon et al define acceptability as “a multi-faceted construct that reflects the extent to which people delivering or receiving a healthcare intervention consider it to be appropriate, based on anticipated or experienced cognitive and emotional responses to the intervention” (28). Usability is defined by the US Food and Drug Administration as the “characteristics of a user interface that establishes effectiveness, efficiency, ease of user learning, and user satisfaction” (29, 30). Because of our emphasis on the clinic workflow not the EIR technology in isolation, in this evaluation we evaluated healthcare worker perception of “usability and acceptability” as a joint construct. The clinic workflow with the EIR inherently depends on both the ease of use of the digital platform and integration of the technology within clinic activities, thus the perceived benefits and challenges of the workflow are not classifiable as only related to usability or only related to acceptability. The semi-structured interview questions contained both open-ended qualitative questions and numeric responses to two scales of interest, both of which measure healthcare worker perceptions of usability and acceptability:

- **The NASA Task Load Index measures:** ask users to describe functions by amount of time pressure they face, frustration experienced, mental demand needed, effort involved, and confidence in the user's performance (31).
- **Likert scale-based workflow acceptability measures:** ask users to rate on a scale of "Strongly Disagree" to "Strongly Agree" their opinions on questions including: "I have enough time to vaccinate all patients attending an immunization clinic"; "The clinic workflow is too complicated"; "We have enough tablets for our clinic to use KIP"; "We have enough staff to adequately use KIP during our immunization clinic"; and "I find KIP easy to use."

In addition to the quantitative indicators, we collected qualitative data from narrative responses to each interview question to complement the statistics with explanatory narrative on usability and acceptability of the EIR modified workflows from the perspective of the healthcare worker.

Data Collection

We collected data using semi-structured interviews lasting approximately 30 minutes each, which we conducted at baseline and after each modification for a total of four interviews per facility (n=24 total interviews). We adapted interview questions from previously validated tools on system use and user satisfaction including the NASA Task Load Index (31). Data collectors recorded responses to open-ended questions by taking notes on the paper-based data collection tools during the interview. All interviews were conducted in English, and Swahili consent forms were available.

To successfully complete all interviews within time and budget constraints of the evaluation, we trained an additional four data collectors to assist with the healthcare worker interviews during the two-week data collection period. The data collector training took place over the course of two days, including a pilot session of the data collection materials at a nearby clinic.

Data Analysis

We examined the data collected from all 24 interviews. We primarily analyzed the qualitative data for results and used the quantitative indicators as supporting comparisons. We used qualitative methods jointly with quantitative methods in order to complement findings and provide richer insight into observed changes in the quantitative indicators between each workflow. The following section describes the analysis methods for each type of data.

Qualitative Analysis Methods

The qualitative data analysis provides meaningful context behind the quantitative indicators, including highlighting challenges and successes of the EIR workflow that are not apparent from solely the quantitative data. We used a thematic coding approach to code the qualitative data collected by the interview data collection tools. The two coders were the two primary data collectors and are English-speakers affiliated with the program that is implementing the EIR. The process of developing the codebook began with a deductive approach by defining high-level themes related to our frameworks for adoption, usability, and acceptability. The two primary data collectors then transcribed a pilot set of two baseline and modified workflow interview transcripts with an inductive perspective to account for emerging codes that were not included in the prescribed frameworks. The coders then convened and reviewed all applied codes and revised the codebook definitions accordingly, including the addition of new codes which had surfaced. The two data collectors then coded all 24 qualitative interviews using the updated codes. Lastly, the coders compared every code and discussed discrepancies until all coded transcripts matched. The coded transcripts were used to assess and group findings on usability and acceptability by clinic workflow. These activities were done using MS Excel and ATLAS.ti.

Quantitative Analysis Methods

The quantitative analysis focused on healthcare worker responses to the NASA Task Load Index and Likert scale-based measures. We reverse coded scale items where appropriate and calculated summary scores for each scale and workflow type. The purpose of this study was exploratory and hypothesis-

generating. Because our small sample size did not meet the assumptions needed to conduct statistical hypothesis testing, we summarized patterns descriptively but did not apply statistical methods to evaluate differences between each modified workflow and baseline. All calculations were done using R Studio.

We calculated the direction of change in indicator score (improved versus worsened) by comparing the facility-specific score for each indicator in the modified workflow compared to baseline. We also calculated a composite indicator for each measure as scored by each facility in each workflow, which we used to compare if a measure was rated more or less favorably than at baseline.

Results

Findings from Quantitative Indicators

Changes by Workflow

Usability and acceptability improved in modified workflows as compared to baseline, as indicated by a higher median Task Load Index scores across health facilities in the three modified workflows (Table 3). For example, the median score for Mental Demand was a 6 at baseline and improved to median scores of 8, 9, and 9 in each the Preparation, Paperless, and combined workflow (respectively). We observed a similar trend for the three dimensions of Time Pressure, Effort, and Frustration, while Performance was rated similarly in all four workflows.

Table 3: Median NASA Task Load Index scores by workflow

Indicator for each facility (n=6)	Median rating / (min, max)** “Baseline”	Median rating / (min, max)** “Preparation”	Median rating / (min, max)** “Paperless”	Median rating / (min, max)** “Preparation + Paperless”
Mental Demand	6 (1,10)	8 (4,10)*	9 (8,10)	9 (7,9)*
Time Pressure	5 (3,10)	8 (3,9)*	10 (8,10)	9 (8,10)*
Your Performance	8 (8,10)	8 (6,9)*	9 (9,10)*	8 (8,10)*
Effort	6.5 (2,10)	8 (5,9)*	9 (9,10)	8 (8,10)*
Frustration	7 (2,8)	9 (3,10)*	9 (6,10)	8 (6,10)*

*n=5 for these scores, one facility missing data due to EIR malfunction during observation day
 **NASA Task Load Index dimensions are measured on a scale of 1-10 with 10 being the most favorable score and 1 being the least favorable score

Healthcare worker responses to the Likert scale-based acceptability indicators, as shown in Table 4 below, showed mixed results. Ratings responding to the question “I have enough time to vaccinate all patients attending an immunization clinic” were a median of 4 (“Agree” on the Likert scale) at baseline, and a median of 4, 5, and 4 in the Preparation, Paperless, and combined workflows, respectively.

Table 4: Median Likert scale scores by workflow.

Indicator for each facility (n=6)	Median rating / (min, max) ⁺⁺ “Baseline”	Median rating / (min, max) ⁺⁺ “Preparation”	Median rating / (min, max) ⁺⁺ “Paperless”	Median rating / (min, max) ⁺⁺ “Preparation + Paperless”
Enough time to vaccinate patients	4 (4,5)	4 (4,5)*	5 (4,5)	4 (4,4)*
Workflow not too complex	**	4 (4,5)*	4.5 (4,5)	4 (4,5)*
Enough EIR tablets for workflow	4 (2,5)	4 (2,5)*	4 (1,5)	4 (4,5)*
Enough staff for workflow	3 (2,5)	4 (2,4)*	3 (1,5)	4 (2,5)*
EIR easy to use	5 (4,5)	4 (4,5)*	4.5 (4,5)	4 (4,5)*
*n=5 for these scores, one facility missing data due to EIR malfunction during observation day				
**question was not asked in a consistent format between the baseline and modified workflow interviews, preventing comparison between baseline versus each of the modifications				
⁺⁺ Factors are measured on a Likert scale of 1-5 with 5 being the most favorable score and 1 being the least favorable score				

Changes by Facility

The median scores presented in Table 3 and Table 4 summarize group-level information on improvements or declines in usability and acceptability in each workflow, aggregated across all six facilities. To understand changes in EIR workflow usability and acceptability at the level of the individual facility we also compared the direction of the score change (improved, worsened, and no change as compared to baseline) in each facility. These changes are presented in **Error! Reference source not found.** and **Error! Reference source not found.** below. In each of these figures, each square corresponds to a single facility’s (facility A, B, C, D, E, or F’s) score for a given indicator (in the leftmost column). The scores at baseline are on the left of the figure and each of the modified workflows are on the right. The green-colored squares indicate an improvement in EIR workflow usability and acceptability from baseline, while red indicates the score worsened as compared to baseline, and grey indicates no change from the

baseline score. The bottom row is the aggregated composite indicator which indicates the direction of change (improved or worsened) by facility across all five indicators.

Figure 2 illustrates change in usability and acceptability scores by indicator at each facility according to the NASA Task Load Index measures. Based on the composite score at the bottom of each column, we can see that for the Preparation workflow, 2 out of 5 facilities experienced a net improvement while 3 out of five gave a worse overall rating (and 1 had no data available). For the Paperless workflow, all 6 facilities experienced a net improvement in scores. For the combined Preparation + Paperless workflow, 4 facilities experienced a net improvement, 1 worsened, and 1 had no data available.

Figure 2: Facility-level changes in usability and acceptability in each workflow, as measured by the five NASA Task Load Index dimensions

Question	Facility Size: Small Large						Small Large						Small Large						Small Large					
	A		B		C		A		B*		C		A		B		C		A		B		C	
Mental Demand (rate on scale of 1 – 10)	8	1	6	10	6	6	8	--	4	9	10	4	9	9	10	8	9	9	8	9	9	9	7	--
Time Pressure (rate on scale of 1 – 10)	10	3	3	6	9	4	8	--	6	9	9	3	10	10	10	9	10	8	8	10	8	10	9	--
Your Performance (rate on scale of 1 – 10)	8	10	8	8	8	9	8	--	8	9	9	6	10	9	9	9	9	--*	8	10	8	9	8	--
Effort (rate on scale of 1 – 10)	8	5	10	2	2	9	8	--	5	9	9	6	10	9	10	9	9	9	8	10	8	9	8	--
Frustration (rate on scale of 1 – 10)	8	8	7	2	5	7	8	--	3	10	10	9	9	6	10	9	10	9	8	10	8	9	6	--
Composite indicator	42	27	34	28	30	26	40	--	26	46	47	22	48	43	49	44	47	35	40	49	41	46	38	--

Color indicates improvement from Baseline

Color indicates less favorable than Baseline

Color indicates no change from Baseline

-- indicates no data collected

* Data was not collected for these facilities due to platform malfunction during these study-days
 Note: A score of 10 is the easiest (better score) and score of 1 is the hardest (lowest score)

Figure 3, below, illustrates change in usability and acceptability scores by indicator at each facility according to the Likert scale measures. Based on the composite indicator, at the bottom of each column, we see that in the Preparation workflow, 3 out of 5 facilities experienced improvement as compared to their baseline ratings, 1 worsened, and 1 had no change (1 had no data collected). In the Paperless workflow, 3 out of 6 facilities experienced improvement, 1 worsened, and 2 had no change. In the

combined Preparation workflow, zero facilities experienced improvement, 2 worsened, and 3 had no change (1 had no data collected).

Figure 3: Facility-level changes in usability and acceptability in each workflow, as measured by Likert scale questions

Question	Facility Size: Small Large						Small Large						Small Large						Small Large																
	A		B		C		D		E		F		A		B*		C		D		E		F		A		B		C		D		E		F*
	Baseline						Preparation						Paperless						Combined																
Enough time to vaccinate patients (Likert)	4	4	5	4	4	4	5	--	4	4	5	4	5	5	5	4	5	5	4	4	4	4	4	--	4	4	4	4	4	4	--				
Workflow not too complex (Likert)	4	5	2	4	5	4	5	--	4	4	4	4	4	5	5	4	4	4	4	5	4	4	4	1	4	5	4	4	4	--					
Enough KIP tablets for workflow (Likert)	4	5	5	4	4	2	4	--	5	2	4	4	4	5	5	4	4	1	4	5	5	4	4	--	4	5	5	4	4	--					
Enough staff for workflow (Likert)	2	4	5	4	2	2	4	--	4	4	2	2	2	4	5	4	2	1	2	4	5	5	2	--	2	4	5	5	2	--					
KIP is easy to use (Likert)	5	5	5	5	4	4	5	--	5	4	5	4	4	5	5	4	4	5	4	5	4	4	4	--	4	5	4	4	4	--					
Composite indicator	19	23	22	21	19	16	23	--	22	18	20	18	19	24	25	20	19	17	18	23	22	21	18	--											

Color indicates improvement from Baseline

Color indicates less favorable than Baseline

Color indicates no change from Baseline

-- indicates no data collected

* Data was not collected for these facilities due to platform malfunction during these study days
 Note: Score of 1 is least and score of 5 is most favorable

Facilities A and B in Figure 2: Facility-level changes in usability and acceptability in each workflow, as measured by the five NASA Task Load Index dimensions Figure 2 and Figure 3 above correspond to the two small facilities (C-F are the large facilities). We did not observe any differences in usability and acceptability of the EIR within small versus large facilities. There is not an identifiable pattern in responses from the two small facilities when compared to the four large facilities.

Both the median scores aggregated by workflow and the directional changes in measures at the facility level signal trends that were further explored in the semi-structured interviews, which are described in the following section.

Findings from Interview Responses

The findings from the key informant interviews support the scale-based ratings in some ways and contradict or offer caveats to the ratings in other aspects. These interview findings are summarized in Table 5 below and discussed in further detail in the following sections.

Table 5: Summary of Qualitative Findings on Workflow Usability and Acceptability

Workflow	Key Workflow Benefits	Key Workflow Challenges
Baseline	<ul style="list-style-type: none"> • The EIR platform was broadly well-liked by healthcare workers • The EIR platform eased certain clinical decision-making and administrative tasks during patient visits <ul style="list-style-type: none"> ○ <i>“KIP is easy and faster to use as compared to paperwork”</i> ○ <i>“KIP is efficient, it makes more work bearable, thinks for you, and gives you direction”</i> 	<ul style="list-style-type: none"> • The time-intensive effort of searching for and entering the same data in multiple places at once • EIR application challenges such as frequent freezing and no network connection to synchronize records with the server • Errors in the KIP application itself which take time attempting to resolve with the patient in the room <ul style="list-style-type: none"> ○ <i>It is “time-consuming to do dual data entry”</i> ○ <i>“Some details lack in KIP yet [are] needed in the book”</i> ○ <i>“Sometimes [lack of] network becomes a very big problem”</i>
Preparation	<ul style="list-style-type: none"> • Some facilities indicated that once the list was created it saved time during clinic visits • The process of creating the list facilitated identification of KIP errors before the patient visit <ul style="list-style-type: none"> ○ <i>“There is “low time pressure to the work during vaccination when appointment list has been made”</i> ○ <i>“During preparation I noticed that some information were (sic) missing in the KIP ... so [the nurse] had to check from the paper [records]”</i> 	<ul style="list-style-type: none"> • Creation of the appointment list from solely the permanent register and daily activity register was time-consuming • HCWs were more likely to perceive the preparation process as a waste of time if the parents and children did not show up for their expected appointments <ul style="list-style-type: none"> ○ <i>“Generating list is not easy since it involves [the] daily activity register and the permanent register.”</i> ○ <i>“Today this was not a good use of time because no children came for immunization”</i>
Paperless	<ul style="list-style-type: none"> • HCWs widely perceive the workflow to save time because of not having to enter data twice; be less mentally taxing because the application calculates and prompts action step-by-step; and prevent errors by displaying all needed information immediately at the point of care <ul style="list-style-type: none"> ○ <i>“I prefer KIP alone without going back to the permanent register.”</i> ○ <i>“You have all the details intact, no thinking”</i> ○ <i>“Workload is reduced because only KIP was used.”</i> ○ <i>“Work was very easy and the system should be changed to paperless. Searching for a child's record took very little time.”</i> 	<ul style="list-style-type: none"> • When KIP was not working, the workflow caused frustration, confusion, and potential errors <ul style="list-style-type: none"> ○ <i>“Prefer using just the KIP tablet, however during times when the network is slow and there is no synching this solution won't work, otherwise it is the best.”</i> ○ <i>“With [these] KIP challenges it creates a burden and more confusion and mistakes might happen”</i>
Preparation + Paperless	<ul style="list-style-type: none"> • User perceptions of the preparation plus paperless combined workflow modification did not have meaningful differences compared to either workflow implemented separately 	

The following sections describe the study findings in more detail by each of the four workflows.

Baseline dual data entry workflow (pre-modification)

The first workflow that was observed and discussed in interviews with the healthcare workers was the baseline state of dual-data-entry workflows. Broadly, healthcare workers liked the current clinic workflow using the EIR platform. However, the use of the EIR in the clinic workflow faced several significant

barriers to consistent high-quality use. Some of the most common challenges described by the healthcare workers at the baseline workflow were duplicate data entry (with both paper and the EIR), technical performance issues with the EIR platform, and inconsistencies between the EIR and clinical practice. Additionally, clinic context-specific challenges outside of the EIR platform itself inhibited usability and acceptability of the technology.

In general, healthcare workers who used the platform described the EIR favorably. They perceived it to be easy to navigate, prevent errors, eased reporting, and that it was a desired future tool to house immunization records. Some clinics also noted the portability of the system to be an advantage. At one clinic where the maternal ward and immunization clinic were physically separated, the HCW was able to carry the EIR tablet to administer an immunization to a child that was just born. The HCW commented that this was preferable for both them and the new mother, as opposed to before when either the HCW had to bring the multiple large paper registers to the clinic or the mother had to bring the new child physically to the immunization room to receive and record the immunizations. In this case, the EIR provided the HCW with flexibility to adapt data collection to be a more appropriate workflow for their physical clinic context.

However, there were pervasive challenges with how the EIR integrates into the workflow in its current form both due to the technology itself and due to contextual factors relating to the clinic environment. Some of the most common EIR platform-specific challenges described by the healthcare workers at the baseline workflow were:

- *Duplicate data entry*: The time-intensive effort of searching for and entering the same data in multiple places at once during this workflow, notably the permanent register, daily activity register, mother-child booklet, and the EIR itself.
- *EIR performance and network reliability*: Obstacles related to the EIR tablet such as frequent freezing, no network connection to synchronize records with the server, and the disappearance of saved records necessitating re-registration of the children.

- *EIR application design*: Errors in the EIR application itself which are inconsistent with clinical practice such as missing antigens in the application and error messages incorrectly indicating default on immunizations.

In addition to EIR-specific challenges which were not remedied for the duration of the data collection period, the baseline state interviews highlighted several additional factors which also affected findings in the subsequent workflow modifications. Some of these factors were that every facility had a unique physical layout, different staff roles at each step of the patient flow, varying numbers of patients, degree of cellular connectivity, and other contextual variables which affected the workflow. For example, several clinics conducted growth monitoring before all immunization visits at a separate desk in the facility, while others conducted all activities in the room where immunizations were delivered. These physical differences and associated staff positions affected the flow of data entry. Additionally, several healthcare workers remarked that they were never trained formally and learned how to use KIP while on-the-job, which some saw as a weakness and others did not consider to be a challenge. Another example was in clinics where they have had to re-purpose other staff to enter data in one tool (either paper or the EIR) while the HCW enters data in the other. In these instances, the workload required of the HCWs by the implementation of the new EIR exacerbated existing constraints, and the dual data entry caused frustration and additional time pressure felt by the HCW.

There did not appear to be different challenges or benefits perceived in small versus large facilities.

The challenges described in the interviews during the baseline workflow state validated our rationales for modifying the workflows to attempt the “preparation” and “paperless” workflows in subsequent days to see if usability and acceptability of integrating KIP into the clinic workflow could improve.

Preparation modified workflow

Healthcare workers were divided on the success of the “preparation” workflow. Their biggest concern with the preparation workflow was the amount of time it took to create the appointment list, but several facilities reported that once the list was made it saved time and helped identify errors early.

We observed that facilities implemented the “preparation” workflow in two different ways despite the same instructions being given. In two of the facilities, healthcare workers created the appointment diary by collecting the mother-child booklets of the patients who had already arrived in the facility that morning and were in the waiting area, checking their records in KIP for accuracy or registering the child if there was no KIP ID recorded, and then returning the booklets back to the mothers. In the other facilities, the healthcare worker created the appointment diary by using the two paper registers to cross-check for expected children before any patients arrived, which provided detail on which children were now defaulting on their immunizations though took significantly more time to create.

Healthcare workers described a mix of positive and negative effects of the “preparation” workflow. Some healthcare workers, particularly those who collected the mother-child booklets of present patients to create the appointment diary, stated they believed it made their jobs easier and less mentally demanding, or that it eased the time pressure during clinic visits. On the other hand, multiple healthcare workers felt that it was a waste of time, especially those in facilities creating the appointment diary from the permanent register who saw mothers with vaccines due not show up for their expected visit. In one large health facility, 23 appointments were expected that day but only 9 children came into the clinic for vaccinations. In another instance, 3 of the 4 expected showed up. Of the facilities creating the appointment diary from the two paper registers, one perceived it to be useful once it was created while one felt it was a waste of effort because none of the mothers came to the clinic that day since it was a market day in the town. Interestingly, one healthcare worker had already been creating a similar appointment diary every evening and calling the mothers with appointments to remind them to come in the next day. This meant the “intervention” workflow was the same as her usual routine, so even though it was perceived as more demanding by some healthcare workers, for this individual it was the same as the baseline workflow and considered usable and acceptable.

Healthcare workers also noted that the EIR system performance problems of freezing and missing records of children was a common and frustrating barrier, just as it was during the baseline workflow. For

example, health workers expressed frustration when they located children in the paper records including their EIR patient ID number, but could not find the comparable record in KIP for an unknown reason, causing additional work to re-register the child within KIP.

The biggest concern with the preparation workflow was the amount time it took to create the appointment list, but several facilities reported that once the list was made it saved time and helped identify errors early. One facility had an instance when preparing the appointment list, where an error in the patient EIR record was identified and corrected, which saved the healthcare worker from having to do that task with a patient waiting in the room. Several other healthcare workers stated that once the list was made, it made their work less mentally demanding to have the list of patients available.

The reported challenges and benefits of the Preparation workflow did not vary by facility size. One small facility had a favorable perception of the workflow while the other had a negative perception. Perceptions of usability and acceptability in the larger facilities were similarly varied.

Paperless modified workflow

Every healthcare worker interviewed preferred the paperless workflow to the baseline (dual data-entry) workflow, with the important caveat that this preference was tied to whether the EIR was working and not missing records.

Participants widely perceived the paperless workflow to save time because they did not have to enter data twice; it was less mentally taxing because the application calculates and prompts action step-by-step; and it prevented errors by displaying all needed information immediately at the point of care.

However, we only observed these benefits when the EIR application was functioning fully as designed, namely when the network was working, records were synching with the server, and there were no errors with saving the vaccines that were administered in the record. We only received these positive comments on the paperless workflow when the EIR was functional. When KIP was not working, the workflow caused frustration and confusion. One HCW also noted with frustration one day that when the EIR was

not working, she still had to administer immunizations, but then often updated the EIR record based on memory which the HCW felt was unreliable and prone to errors. For one facility, we could not collect data on the paperless workflows because the EIR system was not working.

A few healthcare workers also noted that based on the flow of patients in the immunization clinic that it would be more helpful for the EIR to include growth monitoring capabilities. In many of the clinics, the physical layout of activities had mothers and children be processed through a growth monitoring station, which is where initial intake information was recorded and processed before entering the immunization clinic itself. However, the EIR did not include a module to record growth monitoring information, so this order of clinic operations was not consistent with the EIR technology in the majority of observed facilities.

All healthcare workers expressed a desire to move to a paperless data entry workflow once these major issues with the platform were addressed.

Usability and acceptability of the workflow did not vary by facility size. Both small and large facilities conveyed similar opinions that when KIP is working, the workflow saves time and is less mentally demanding, but when KIP is freezing, missing records, or experiencing other functionality problems there is a high degree of frustration and the clinic workflow cannot function properly.

Preparation and Paperless combined modified workflow

Based on interview conversations, user perceptions of the Preparation plus Paperless combined workflow modification did not have meaningful differences compared to either workflow implemented separately. For example, issues with KIP functionality remained common complaints with the workflow as they did in the paperless-only workflow the previous day. Similar challenges to the preparation workflow such as perceived waste of time and time-intensive process to create the appointment diary were noticed as well. There was, however, one healthcare worker who stated she prefers this combined workflow out of the three options, though they did not provide an explanation for this preference. As with the “preparation”

and “paperless” workflows separately, there were no differences between small versus large facilities in perceptions of usability and acceptability of this combined workflow.

Discussion

Summary of key results

Several themes emerged from the interviews before and after the three workflow modifications. At a high level, participants indicated almost universally that the paperless workflow was more acceptable than the baseline dual-data-entry workflow, while the dual data entry, preparation, and combined workflow had more mixed reception. There were several benefits perceived by the healthcare workers in modifying the workflows for use of a paperless process and preparation of a daily appointment list. These include decreased mental demand, decreased frustration, and increased ability to address errors in immunization records. However, there were also several challenges which must be addressed in the clinic environment, such as number of staff and network connectivity, and the EIR platform itself, such as freezing and missing records, before these new workflows are considered for broader implementation.

In comparing the quantitative indicators to the qualitative findings, we saw some findings complement each other and some findings contradict each other. For example, the paperless workflow scored high on nearly all quantitative measures, but the qualitative interviews for the paperless workflow elicited additional issues which affect the consistency and reliability of these positive scores such as the EIR tablet freezing, connectivity challenges, missing records in the system, and chronic understaffing which may preclude full implementation of that workflow until those challenges are addressed. We also found variation across all health facilities, as described by both qualitative interview responses and the quantitative indicators, such that there was no universal “best way” identified to implement a workflow. Each clinic approached use of the EIR in a manner tailored to fit their individual clinic environment and resources.

Explanation of Findings

Our findings can be explained by the several layering elements of clinic context, EIR system, and workflow, which are all interrelated (22) and can have cascading effects, positive or negative, on ultimate usability and acceptability of the EIR implementation from the healthcare worker perspective (22, 24, 32). The EIR application itself is the same at each facility, but the way it is integrated into the workflow can take many different forms. Modifying the workflows can address some of these factors positively or negatively but not others. Our findings demonstrate that when HCWs are given a baseline enabling context, a reliable system, and allowed flexibility in the workflow, acceptability of the workflow may be enhanced.

Our findings add to the large and growing body of literature regarding upscaling of EIRs and other digital health technologies. The five interacting elements of a work system which are described by Carayon et al as factors to consider when designing work – individual, task, technology, environment, organizational factors – is one such example (22), as is a recent evaluation of an EIR implementation in Pakistan (21) which lists ease of operability, satisfaction with reliable data, results-based field support, and HCW empowerment as enablers of EIR adoption specifically. Our evaluation bridges some of these elements by connecting elements of a work system to EIR technology specifications.

Clinic context

Clinic context affected all workflows whether measuring by quantitative or qualitative indicators. Clinic context includes number of staff, number of patients seen, the physical layout of the clinic, and clinic ward structure. Each clinic had a unique context, from configuration of individual staff, to clinic flow of activities, to environmental elements. This context can either precondition the EIR to be successfully integrated into the workflow or have negative consequences for acceptability of the EIR if the clinic does not provide a supportive environment for introducing a new intervention. The lack of network connectivity in particular was a common barrier both in our results and in other EIR evaluations (21).

Our workflow modifications, notably the fully paperless workflow, were able to improve the way HCWs interact with the EIR during immunization sessions, but could not change the surrounding clinic context. Examples of this included when facilities had consistently poor network connectivity, and when the HCWs at the facility expressed lack of adequate training as a concern. These concerns were all raised during the baseline workflow interviews and did not change during any of the modified workflows. We saw this in the quantitative indicators that had to do with staffing and number of tablets (context-based) whose values did not change, compared to the indicators which asked questions about solely how the HCW and the system interacted (e.g., mental demand, frustration) which did change upon modifying the workflows.

Without an enabling context including adequate connectivity and staffing, match between the EIR system and reality was poor and contributed to low degree of acceptability and usability of the workflow for the HCWs.

EIR System

If the clinic context presented a favorable environment for EIR, the next layer of factors which needed to be in place to support acceptability of the EIR workflow was a fully functioning EIR system. During the baseline workflow interviews, system errors and application design concerns were described from the outset as negatively affecting usability and acceptability. These challenges persisted in the modified workflows and negatively affected usability and acceptability. However, when the EIR was working as designed, the HCWs noted that there was less mental demand to administer vaccines, appreciated that the EIR prompted them to administer the correct vaccines, and that it was easier to follow up with defaulters. Other examples of the EIR system negatively affecting workflow acceptability were the lack of growth monitoring in the EIR application, when the physical set-up of most clinics integrated growth monitoring with immunization services.

These findings demonstrated that without system reliability and well-designed software, HCWs were unable to use the EIR effectively in their workplace, leading to lower acceptability and possibly data

quality. But, when the system was working, it laid the foundation for acceptable integration of the EIR into the clinic workflow. The importance and positive effects of reliable and well-designed digital health technologies have well-documented positive effects on system acceptability as well (15, 21). Though rather than focusing on the technology itself, the emphasis of this study is on the acceptability flow of work surrounding the system. Even if a technology operates perfectly as designed, it can still pose negative consequences depending on the manner in which it is used (17).

Workflow to match EIR system and reality

Once there was supportive clinic context and a fully functioning EIR system as foundational required characteristics, HCWs could establish a clinic workflow that best integrated the system into their reality of delivering care. Without the workflow and system meeting the HCWs real-world needs, the EIR workflow was not considered acceptable by the HCWs. We saw many examples of positive and negative effects of system-reality match in the workflows we evaluated, such as HCWs being able to carry the portable EIR tablet to the maternity ward, some HCWs feeling frustration at patients not showing up for their appointment day during the preparation workflow, and some clinics re-purposing staff for dual data entry. Further, in addition to the design flaws in the technology itself described above, we observed instances of errors in patient data entry resulting from a workflow mismatch. For example, when the EIR system was frozen or not connecting to the server or if the clinic was too busy to allow for dual data entry, HCWs reported that they were then obligated to fill in records based on memory later. The HCWs described that this made the records more prone to errors. In this way, some EIR data entry errors were rooted both in the technology itself and in the workflow surrounding that technology. As described by the Institute of Medicine in their landmark 1999 report on medical errors, “all technology introduces new errors, even when its sole purpose is to prevent errors” (33). Organizations implementing new technologies, such as EIRs, should anticipate this and seek strategies to mitigate these errors where possible (17).

These results demonstrated the importance of not designing the EIR with a “one size fits all” approach, since each clinic used the system and implemented a workflow which met the needs of their individual workplace specifically. There were too many unique aspects of each clinic to design a top-down workflow around. Rather, the EIR should empower the HCWs with flexibility to use the new EIR in whatever manner is appropriate for their context and pre-existing operations. This supports findings from previous studies on the parallel development of both technical systems and the social systems that surround them (32, 34)—specifically that they should be designed with “minimum critical specification” such that users can develop appropriate configurations to suit their needs. To further enable facility-level adoption and integration of the EIR into the workflow, HCW-led support measures such as peer-to-peer support groups, champion-based approaches, and other user-driven mechanisms could potentially be valuable means of identifying best practices for implementation in specific contexts, though additional research is needed on the utility of these in different contexts.

The EIR application itself is the same at each facility, but the way it is integrated into the workflow can take many different forms. Changing the enabling environment or infrastructure of the clinic is more resource-intensive than modifying workflows, and the EIR should be designed in such a way to enable this flexible accommodation from facility to facility. Our findings indicate that if HCWs are given a reliable EIR with adequate foundational context, having that degree of flexibility to change their workflow can enhance acceptability of the new tool. Without this flexibility, developers and implementers of the system risk the negative consequences of making decisions for users (HCWs) rather than empowering HCWs to make their own decisions (32). Many health innovations involve introducing a new process rather than a new product (35). In the case of a new EIR, both a new product and a new process are being introduced, indicating that it is crucial for successful implementation to result in both a successfully integrated workflow and a fully functional system design. Though, this area remains understudied: much of the existing evidence on adoption of EIRs and other digital health technologies has focused on application development or before-and-after effects of implementation on service coverage

(21). Our findings contribute to filling this gap in understanding of the factors at which facilitate adoption of digital health technologies.

Connected relationships

We can see that these several layering factors of context, system, and workflow were all interrelated and can have cascading effects, positive or negative, on ultimate usability and acceptability of the EIR implementation from the healthcare worker perspective. When there was an obstacle or disconnect between the clinic context, new EIR system, or inflexible workflow, the HCWs inevitably found the new system to be not usable or acceptable, which can ultimately lead to poor data quality and use. Even with seamless integration of the EIR into clinic workflows, contextual challenges with the technology, personnel, and enabling environment levels can still pose challenges (21-23). Similarly, even if a clinic's context is well-suited for EIR adoption with trained staff, reliable electrical power, and adequate network connectivity, if the system is poorly designed without the HCW needs in mind then it will have cascading negative effects on acceptability from the HCW (18, 35, 36). Thus, all of these factors must be carefully considered during implementation efforts. This interrelationship between elements of a work environment which enable adoption of new technologies is supported by many studies in additional contexts (22, 23, 32).

Strengths and limitations

Our sample size was appropriate for generating hypotheses on promising workflow modifications to be scaled up and further studied for efficiency and effectiveness. We did not seek to systematically evaluate a range of clinic context factors as present or absent, though future study in a wider set of sites could undertake this type of work to assess a variety of contextual conditions and examine whether workflow modifications work better in some contexts but not others.

Our study design also did not allow for robust statistical testing of the quantitative indicators, which could be addressed in future studies evaluating a larger set of facilities. Further, the quantitative scales we used have not been validated in other clinic settings, limiting our ability to generalize to other contexts or draw

conclusions about the relationship between the quantitative scores and future likelihood of the acceptability of the EIR.

This study demonstrated that among a smaller set of facilities, qualitative interviews of the HCWs using the EIR can reveal important issues in the match between the EIR system and the clinic context where it is used. Interviews such as these remain an important part of EIR implementation evaluation and improvement. In future studies, interviews from healthcare workers would be useful at multiple points in over the course of rollout to identify iterative improvements to implementation. The quantitative data in our study provided high-level indicators on usability and satisfaction with use of the EIR, though that method of assessment may prove to be more valuable when implemented at a later state of EIR rollout when more clinics are assessed on those factors.

Additionally, in implementing the workflow modifications, it is possible that a single day of training to orient the HCW to the new workflow and conduct data collection was not a long enough period of time for it to be adopted and measured as intended. Relatedly, for the combined preparation plus paperless workflow, our results may be partially explained by a learner effect, where the HCWs became more accustomed to the workflow on the second day of doing it and therefore responded with less negative feedback than when the preparation workflow was first implemented alone.

Despite these limitations, our evaluation provides a valuable exploration of challenges and benefits to EIR workflow implementation from the perspective of the HCW. Much of the existing evidence on adoption of EIRs and other digital health technologies has focused on application development or before-and-after effects of implementation on service coverage (21). Our findings contribute to filling this gap in understanding of the factors which facilitate adoption of digital health technologies. Based on these findings, we recommend further study on improving clinic contexts and designing EIR systems to maximize flexibility.

Conclusion

Fully paperless EIR implementation shows great promise from a workflow acceptability standpoint, contingent upon presence of supporting contextual factors and resolution of system performance and design challenges. A reliable EIR will provide adequate flexibility for HCWs to implement the new system in their unique clinic context. Future studies, rather than trying to identify a singular best workflow should look for ways to maximize flexibility, reliability of the app, and strong enabling environments, and let the HCWs in each clinic match the EIR to their real-world context to have the best results for data use.

Qualitative interviews were more informative than the quantitative indicators in eliciting actionable improvements to make to an EIR workflow implementation. Quantitative indicators can be directionally beneficial but may be more suitable for larger-scale monitoring in later stages of implementation. Future EIR implementation stands to benefit from a standardized and reliable set of quantitative indicators to support continued monitoring of EIR adoption acceptability during implementation both for Siaya's program and for other efforts around the globe as digital health interventions become more widely used.

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