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The implementation of an integrated e-leprosy framework in a leprosy control program at primary health care centers in Indonesia

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ABSTRACT

Background and Objective: The implementation of health information systems (HIS) could overcome obstacles in human resources and infrastructure at primary health care centers (PHCs). This study involved an e-Leprosy framework being integrated into the real setting of a leprosy control program in Indonesia. The objectives of this implementation study were to integrate e-Leprosy into a leprosy control program at 27 PHCs in Pekalongan District. Central Java Province, Indonesia to explore factors related the success or failure of such an implementation regarding the usability, involvement, and acceptance of e-Leprosy by PHC staff and to evaluate the effect of the implementation on leprosy patient attendance at PHCs. This paper is based on the Standards for Reporting Implementation Studies (StaRI) statement.

Method: This study used mixed methods implementation research with longitudinal analysis and involved two groups of participants: Leprosy Surveillance Officers (LSOs), patients, and the relatives of patients. This study involved four phases consisting of preparation, baseline assessment, intervention, and evaluation. The qualitative study conducted focus group discussions and in-depth interviews. The e-Leprosy program automatically sent SMS reminders regarding leprosy treatment to the LSOs, patients, and patients' relatives every month.

Findings: This study determined that LSO had difficulties related to their workloads in PHCs while managing information and monitoring treatment and contact after release from treatment. The baseline assessment phase found that LSOs in Pekalongan District were unfamiliar with email but familiar using the internet. Overall, LSOs had a positive perception of the e-Leprosy program. The usability of this e-Leprosy program tended to increase over time, while acceptance of the e-Leprosy exhibited a significant relationship with computer and internet fluency ($r = 0.48$, $p < 0.05$) and age ($r = 0.621$, $p < 0.01$). The responsible patients correlated ($r = 0.67$, $p < 0.01$) with involvement in the e-Leprosy program. This study revealed that patient reminders increased on-time attendance by 13.9 % ($p < 0.01$ with OR = 2.41).

Conclusion: Factors that should be considered during implementation HIS included the digital gap, PHC's staff workload, as well as the level of commitment and leadership in the health office.

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1. Introduction

The World Health Organization (WHO) has listed neglected tropical diseases as a continuing major health issue in certain countries, with leprosy representing one of many such diseases in Indonesia. Of the 200,000 new leprosy cases occurring worldwide each year, approximately 80 % occur in India, Brazil, and Indonesia [1,2]. In 2017, Indonesia reported 15,910 leprosy new cases, even though 38 countries reported < 10 leprosy cases and 30 countries reported zero cases [3]. Leprosy patients require regular multi-drug therapy (MDT)[1] treatment for up to a six- or 12-month period, depending on their leprosy type. As such, the adherence of patients to MDT regimens represents a great challenge since the long treatment duration may lead to residual sources of infection, incomplete cure, persisting infections, irreversible complications, transmission to new susceptible individuals, multi-drug resistance, and disability or deformity development [4–6]. Therefore, an integrated and innovative approach—such as using a health information system (HIS)[2] —is required to improve patient adherence to MDT regimens and leprosy elimination programs [7]. To date, a limited number of studies have embraced digital health in leprosy control programs, despite digital health innovations being recommended to improve disease programs in developing countries, which involve disease prevention, surveillance, self-management, and compliance [8,9]. The adoption of digital health in leprosy control programs is concordant with the *Global Leprosy Strategy 2016–2020*, which promotes innovative approaches such as the deployment of digital health with public health initiatives [10].

Implementation science (IS) has been defined as the scientific study of methods to promote the systematic uptake of clinical research findings and other evidence-based practices into routine practice [11]. It is a new field to fill the gap between research and practices since it is embedded in reality and involves people working in the real world (practitioners as opposed to individuals performing research only) [12]. Implementation research frameworks are increasingly applied and widely adopted in health service research; unfortunately, no implementation research model specific to eHealth exists to date, especially in Phase IV of implementation. Notably, a Phase IV study accommodates or encourages a diversity of patients, professionals, and healthcare contexts to improve implementation in real-life settings [13].

Notably, medical informatics has suffered from a lack of implementation research because the progress translation from research into practice has been excruciatingly slow [14]. Some models of implementation research that are likely relevant to eHealth implementation research include (1) the Evidence Integration Triangle; (2) Expanded Chronic Care Model; (3) Health Literate Care Model; and (4) the RE-AIM Model (Reach, Efficacy/Effectiveness, Adoption, Implementation, and Maintenance) [15].

Indonesia has approximately 9000 primary health care centers (PHCs)[3] in 530 districts, which serve to detect new cases, monitor treatment, and evaluate the outcome of the leprosy control program [16]. Regular and on-time MDT treatment in PHCs by leprosy patients is the key factor in ensuring successful therapy and better outcomes.

To the best of our knowledge, this study represents the first piece of implementation research on the Indonesian leprosy control program using the deployed e-Leprosy framework. The e-Leprosy program is a web-based application featuring automated SMS reminders in which the sending and receiving of notification messages among leprosy surveillance officers (LSOs) and the developed system. The e-Leprosy program has been implemented at 27 PHCs in Pekalongan District, Indonesia.

[1] MDT: Multi Drug Therapy

[2] HIS: Health Information System

[3] PHC: Primary Health Care or Public Health Centers

The objectives of this implementation study were to integrate e-Leprosy into the real setting of the leprosy control program and to evaluate the effect of interventions on this program (i.e., timely follow-up visits by leprosy patients). Furthermore, we explored factors related to the success and failure of e-Leprosy program intervention, such as digital health literacy, usability, and the involvement and the acceptance of the program by LSOs. This paper is reported based on the StaRI statement and describes the process and outcomes of each phase of the e-Leprosy program intervention in PHCs.

2. Method

2.1. Description

2.1.1. Research design

This study involved implementation research using a mixed methods study design. A mixed methods design was chosen because it provides a practical method of understanding multiple perspectives, different types of causal pathways, and multiple types of outcomes as accepted features of implementation research problems [17–19].

We applied the RE-AIM implementation research model since the focus of the model is research and its translation into practice. Furthermore, the RE-AIM framework is intended to assist in the planning, conduct, evaluation, and reporting of research studies rather than to only guide the implementation of a specific innovation [20–22]. The models of implementation study have steps that consist of several activities, including: (1) To identify care gaps and the need for change; (2) To identify barriers to the consistent use of guidelines; (3) Review evidence on implementation interventions; (4) Tailor or develop interventions to improve performance; (5) Implement the interventions; (6) Evaluate the process of implementation; (7) Evaluate the outcomes of the interventions [23].This implementation study reported based on the Standards for Reporting Implementation Studies (StaRI) statement [24]. In the present study, we used the StaRI statement since it was expected to determine the key components of the implementation strategy, process, and health outcomes that should be measured [25]. Notably, specific health informatics reporting standards e.g., Statement on Reporting of Evaluation Studies in Health Informatics (STARE-HI) and a guideline for Good Evaluation Practice in Health Informatics (GEP-HI) seem to focus more on evaluating digital health as opposed to reporting on the real-setting implementation, exploring neither the process or the potential factors affecting implementation [26]. However, the present study utilized STARE-HI for the section on reporting a description of the e-Leprosy intervention [27].

In the present study, we sought to understand and develop an e-Leprosy intervention within the real-world PHC conditions of Indonesia so that the intervention did not control the conditions or remove influences such as the causal effects of the implementation. This research study was more focused on the process of integrating the e-Leprosy program in the real world by exploring factors of success and failure during the integration, which consist of digital health literacy, usability, the involvement of patients and stakeholders, and the acceptance of the program.

For this study, we selected Pekalongan District, Indonesia as the pilot project area. This study describes four phases consisting of preparation, baseline assessment, intervention, and evaluation. The long-term observations and interventions were performed in the real setting of a leprosy control program to capture and understand the routines of PHC practices. These approaches represent the first steps in developing a workable strategy to enable the integration of self-management into practice.

2.1.2. Context

2.1.2.1. Preparation phase. In the preparation phase of the study, we conducted in-depth interviews and focus group discussions (FGDs). The informants consisted of one leprosy supervisor from the provincial

health office, one staff of the National Consultant of Leprosy, two staff of the leprosy control program, two staff of the Center for Disease Control of the Pekalongan District Health Office, and three PHC Managers and their LSOs.

Furthermore, the qualitative study was conducted at the Regional Health Office in Central Java Province, Pekalongan District, at the PHC level to capture the perspectives of LSOs regarding the obstacles and challenges of the leprosy control program. At this stage, we also investigated an appropriate health informatics intervention in the belief that using the perspectives of LSOs in the development e-Leprosy framework would lead to more successful outcomes in subsequent intervention stages.

The results of the qualitative study were then confirmed through a quantitative study by distributing a questionnaire during monthly meetings at the Pekalongan District Health Office.

2.1.2.2. Baseline assessments. We performed a baseline assessment for 27 LSOs at PHCs and one district leprosy supervisor. The assessment aimed to explore the digital health literacy of leprosy officers in terms of their understanding of using mobile phones, the internet, and computers. In this phase, we used standardized questionnaires such as the computer, email, and web fluency questionnaire (CEW)[4] [28] and eHealth literacy scale (eHeals)[5] questionnaire [29]. The questionnaires were distributed to LSOs during monthly meetings at the District Health office before the intervention began.

2.1.2.3. Intervention phase. The e-Leprosy framework was deployed in all of 27 PHCs at Pekalongan District, which is a rural district and endemic leprosy area in Central Java Province, Indonesia. The integration process involved collaboration with a leprosy district supervisor at the District Health Office, who involved the PHC staff managing the leprosy control program (i.e., LSOs).

Every month, the Pekalongan District Health Office regularly organized meetings for LSOs. During these meetings, the socialization and integration processes of the e-Leprosy program were deployed. Furthermore, these meetings were also used for training purposes, encouragement, and to motivate LSOs to become actively involved in the e-Leprosy program and to distribute the usability questionnaires four times during the e-Leprosy program intervention.

2.1.2.4. Evaluation phase. In this study, we evaluated the effect of the e-Leprosy program intervention from July 1, 2014 to June 31, 2016. We evaluated the on-time attendance of patients at the PHC according to the schedule mentioned in the SMS reminders. LSOs were evaluated for their perception of e-Leprosy through a distributed questionnaire at the end of the study during regular meetings at the Pekalongan Health Office.

2.1.3. Target

This study targeted patients registered from July 1, 2014, to June 31, 2016, patients' families, and 27 LSOs in PHCs, and leprosy district supervisor at the District Health Office. We enrolled patients and their families who were willing to share their phone numbers and receive monthly SMS reminders during leprosy treatment.

LSOs who had leprosy patients in their PHC were involved in this study by inputting patient data and replying to the e-Leprosy program. LSOs were required to reply to the e-Leprosy program by SMS if patients came to their PHCs for MDT treatment.

2.1.4. Description of intervention

This implementation study deployed e-Leprosy at PHCs of the Pekalongan District Health Office. Pekalongan District is a rural area of the Central Java Province of Indonesia with 27 PHCs as health facilities to manage the leprosy control program. PHC locations were distributed into sub-districts and the sub-districts are unfortunately different with respect to internet quality and mobile phone networks.

The e-Leprosy framework was the HIS model for the routine health service of leprosy patients, monitoring MDT, surveillance after release from treatment, and contacts tracing of patients. E-Leprosy program is a web-based application system enriched with bidirectional SMS notifications for LSOs, but only involves one SMS direction (outgoing) for leprosy patients and family (Fig. 1).

The e-Leprosy framework was made exclusively for leprosy disease using open-source software. The technical specification of the e-Leprosy server was run on the Linux Deeping 2014.1 Operating System (Ubuntu Trusty Derivative), Kernel Version 3.13.0 − 24-generic SMP 64 bit, XAMPP for Linux 64bit 1.8.3 − 4, Gammu Version Gammu SMSD: 1.33.0 and OpenSSH Server: 1:6.6p1 − 2ubu.

The e-Leprosy program automatically sent SMS reminders to leprosy patients to take MDT at PHCs for 6 or 12 months. The reminders were sent to LSOs, patients, and patients' relatives who were included in the e-Leprosy database every month, three days before and after the due date of MDT from July 1, 2014 to June 31, 2016.

The design of e-Leprosy resulted in LSOs only receiving reminders for registered patients in their PHCs, with 22 of 27 PHCs having had leprosy patients. LSOs were expected to reply to e-Leprosy when patients already took the MDT (Table 1) so that the updated MDT reminder scheduled for the following month was sent based on their replies.

A total of 22 LSOs, 101 patients, and patients' families regularly received an SMS every month during patient treatment based on each patient's leprosy type. Reminders were sent the Paucibacillary (PB) type for six months and the Multibacillary (MB) type for 12 months. The e-Leprosy program was designed to stop sending messages when the program recognized that patients had already completed their treatments. To prevent incomplete treatments, these reminders would be resent if the e-Leprosy program did not receive any SMS replies for three consecutive months (Table 1).

2.1.5. Sub-groups

The intervention of the e-Leprosy program involved two groups of participants. The first group was comprised of patients and their families, while the second group comprised LSOs working at PHCs. While analyzing the process, we then divided the first group of participants into two sub-groups consisting of before- and after-intervention patients. The proportion of on-time attendance of patients who took MDT each month is compared before and after the intervention.

The second group of participants recruited all 27 LSOs and one leprosy district supervisor. In addition to replying to the e-Leprosy program, the LSOs were involved in the e-Leprosy framework by collecting and inputting patient data into the e-Leprosy program, including information such as patient demographics, patient and relatives' phone numbers.

2.2. Evaluation of phases

2.2.1. Outcomes

2.2.1.1. Preparation phase. The preparation phase aims to understand the flow of information, to determine out the need for information, to receive feedback on difficulties in the leprosy control program, and to ascertain the feasibility and appropriateness of the HIS model. The results of the preparation phase were to develop the e-Leprosy framework and the description of obstacles to the leprosy control program, which brings attention to factors such as problems related to workload, training and competency, job descriptions, and infrastructure.

2.2.1.2. Baseline assessment. The outcomes from the baseline

[4] CEW: Computer, Email, Web Fluency
[5] eHeals: eHealth Literacy Scale

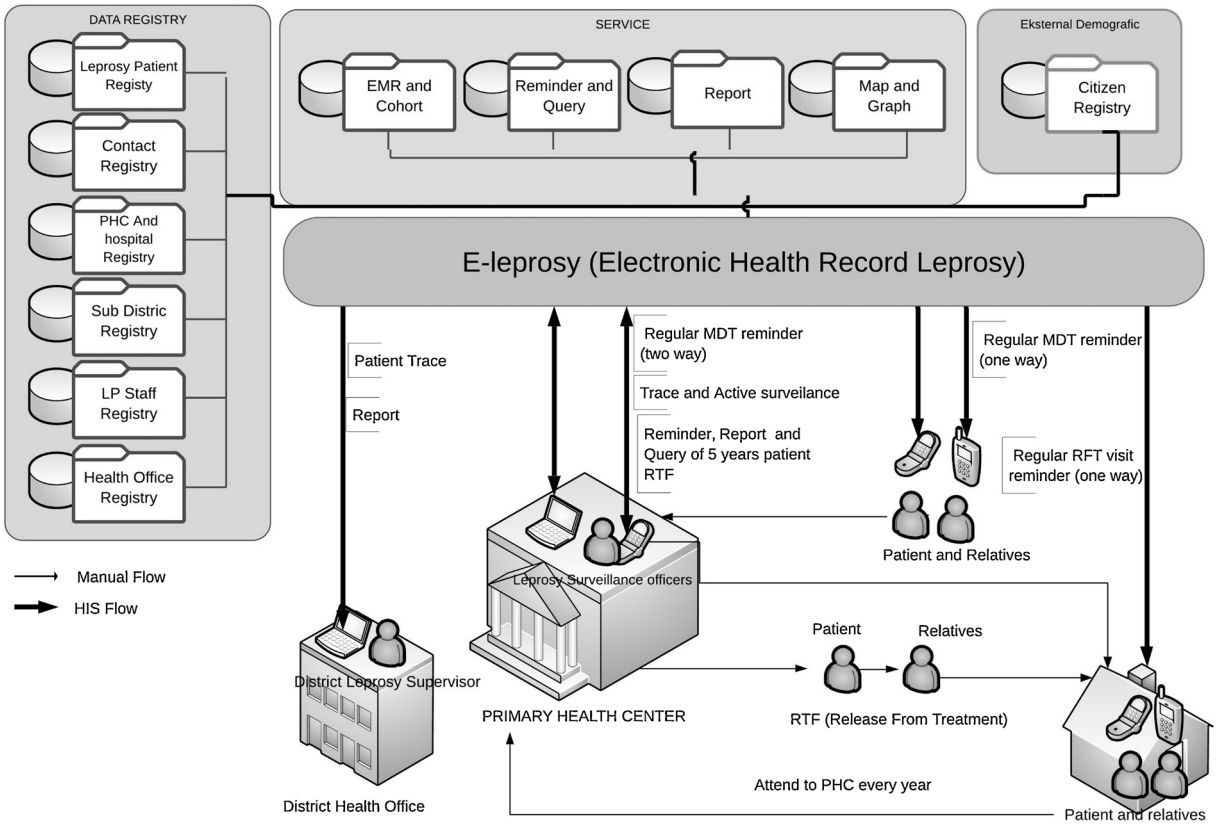

Fig. 1. e-Leprosy framework for the leprosy control program in Pekalongan District, Indonesia.

Table 1
The format of e-Leprosy SMS reminders sent to leprosy surveillance officers (LSOs), patients, and patients' families.

Function	Format	Example
The format of the SMS reminders sent to patients, their relatives, and LSOs	**Patient** < space > **name #no.reg#ID#PHC** < space > **name of PHC#please** < space > **take** < space > **MDT** < space > **number** < space > **X#Date** < space > < **yyyy/mm/dd** >	Patient Elly#123,456,789#987,654,321#PHC Buaran#please take MDT number 7#Date 2014/10/28
The format of the SMS reply sent by LSOs	**MDT** < space > **numberX#Patient** < space > **name# no.reg#ID# PHC** < space > **name of PHC#please** < space > **take** < space > **MDT** < space > **number** < space > **X #Date** < space > < **yyyy/mm/dd** > ***(LSOs only edit the underlined text with the MDT number and the date on which patients underwent MDT)***	MDT number 7#Patient Elly#123,456,789#987,654,321#PHC Buaran#please take MDT number 7#Date 2014/10/29
The format of the SMS reminder to avoid defaulting, sent to patients, their relatives, and LSOs	**Patient** < space > **name#no.reg#ID#PHC** < space > **name of PHC# did not** < space > **take** < space > **drug** < space > **since#date** < spasi > < **yyyy/mm/dd** >	Patient Elly#123,456,789#987,654,321#PHC Buaran#did not take drug since#date 2014/11/29
The format of the SMS reply to avoid defaulting, sent by the LSOs	**MDT** < spasi > **numberX/DEFAULT/DEAD/MOVE/RFT#** **Patient** < spasi > **name#no.reg#ID# PHC** < spasi > **name of PHC# did not** < space > **take** < space > **drug** < space > **since#date** < spasi > < **yyyy/mm/dd** > ***(LSOs edited the underlined text in the MDT status and the date the status was updated)***	Default#Patient Elly#123,456,789#987,654,321#PHC Buaran#did not take drug since#date 2015/05/29

assessment were characteristic of leprosy staff and the digital health literacy of LSOs. These outcomes were measured by the standardized CEW [28] and eHeals questionnaires. The eHeals questionnaire has responses ranging from strongly disagree to strongly agree, with scores ranging from 1 to 5 [29]. The CEW questionnaire is widely used to assess people's proficiency with computers, email, and the internet, and eHeals is applied to measure knowledge of computers (or of a particular language or skill) to a level conducive to achieving health-related goals [30,31]. Notably, these skills are considered influential for health professionals in this digital era.

2.2.1.3. Intervention phase. The outcomes of this phase compromised the usability and involvement of the LSOs and patients in the e-Leprosy program. The proportion of involvement of both the LSOs and patients were reported. The involvement of patients was defined as the numbers of patients and families that were willing to share their phone numbers and receive SMS reminders every month to take MDT at PHCs, while the involvement of LSOs was defined as the numbers of SMS responses that were sent to the e-Leprosy program after patients received MDT from PHCs.

The usability of e-Leprosy by LSOs was measured using the standardized Computer System Usability Questionnaire (CSUQ). This questionnaire is widely used to assess usability with a system in non-laboratory settings [32]. Usability was measured four times during the e-Leprosy intervention and usability trends are reported.

2.2.1.4. Evaluation phase. The outcomes of the evaluation phase were the main outcomes of this implementation research program since it reported the impact of the e-Leprosy intervention. These outcomes were the proportion of on-time attendances (OTAs)[6] of leprosy patients as well as the perceptions of LSOs regarding the e-Leprosy program, which ranked the usefulness, easiness, and suitability need.

2.2.2. Process evaluation

2.2.2.1. Preparation phase. In the preparation phase, we evaluated the condition of and obstacles to the leprosy control program at PHCs based on the results of the qualitative and the quantitative study to develop a framework to match the resources available at the PHCs.

2.2.2.2. Baseline assessment. In the next phase of this study, we evaluated the digital health literacy of LSOs as the baseline of the next intervention phase. The result of the baseline assessment was used to understand their computer and internet skills to generate training and motivate LSOs to become actively involved in the study.

2.2.2.3. Intervention phase. In the intervention phase, we monitored the usability of e-Leprosy through a questionnaire that was periodically distributed four times during the intervention. Furthermore, this study evaluated the involvement of LSOs by comparing the SMS reply with the attendance events recorded in the manual leprosy registry cohort at PHCs. We also encouraged the LSOs to input the data of patients who were willing to share their phone numbers and receive monthly SMS reminders during their treatment.

2.2.2.4. Evaluation phase. We evaluated the impact of the e-Leprosy intervention by evaluating the OTAs of leprosy patients and LSOs' perceptions of the e-Leprosy program. We recorded patient visit dates to measure the periods between MDT collections, and identified patients taking the blister packs ≥ 31 days as the late patients. In this phase, we also compared the proportion of OTAs the patient attending among patients before and after the intervention group.

2.2.3. Economic evaluation

The e-Leprosy platform was created exclusively for leprosy disease using open-source software, including Linux and Gammu. No existing open-source platform is available due to the design uniqueness—specifically the SMS reminder for e-Leprosy.

Based on the results of the preparation phase and baseline assessment, SMS was chosen as the most applicable platform matching the infrastructure and resources of PHCs. Furthermore, the cost of an SMS reminder is very low because various SMS packages are available from telecommunication services providers in Indonesia. Therefore, SMS could utilize to deploy this e-Leprosy framework for the leprosy control program in Indonesia.

2.2.4. Sample size

We observed two groups of patients attending PHCs before and after the intervention of the e-Leprosy program. The first group, formed before the intervention, was registered with 218 patients from June 1, 2012 to June 31, 2014. The second group was registered with 177 patients from July 1, 2014 to June 31, 2016, of which 101 patients were involved in the intervention phase. This reduction in patients was due to the number of families that were willing to share their phone numbers and receive SMS reminders.

2.2.5. Analysis

The data were analyzed using Microsoft Excel and IBM SPSS 20. The Spearman's Rank Correlation test, Chi-squared test, and T-test were used to analyze factors influencing the involvement of patients and PHC workers in the e-Leprosy framework and the impact of the intervention.

2.2.6. Sub-group analyses

The e-Leprosy program involved two groups of participants in the framework: LSOs and patients, along with patients' relatives. In this study, we collected patient data of before and after intervention using registry cohort and e-Leprosy databases, respectively.

We recruited nearly all of the 27 staff members responsible for the leprosy control program (i.e., LSOs). The LSOs received and replied to the e-Leprosy program upon their patients receiving MDT. The involvement of LSOs was measured based on their replies to the e-Leprosy program. The numbers of SMS messages sent to the e-Leprosy program were cross-checked with the attendance events recorded in the paper-based patient records and the manual leprosy registry cohort at PHCs.

3. Results

3.1. Preparation phase

3.1.1. Qualitative study

The qualitative study resulted in PHCs encountering several difficulties in managing the information of leprosy patients and requiring help from a HIS, while patients had low-mid end mobile phone and patients' relatives were not active in their treatment overall. Notably, the results of the qualitative study have been published elsewhere [33]. The outcome of the qualitative study was then confirmed with the quantitative study to explore greater details regarding the condition of the leprosy control program at PHCs.

3.1.2. Quantitative study

This quantitative study aimed to confirm the qualitative results and investigate obstacles to the leprosy control program at PHCs. The questionnaire was distributed to 25 of 27 LSOs and contained a seven-item Likert scale. We deleted neutral item options to avoid confusion for LSOs since they most likely would provide answers with no opinion. Therefore, the score range was 1–6, with the response ranging from highly disagree to highly agree. Obstacles to the leprosy control program can be divided into workload, training, competences, job descriptions, infrastructure, and finance. Fig. 2 shows that the biggest problem of the leprosy control program was related to workload followed by infrastructure.

We observed that 100 % of LSOs experienced a heavy workload at PHCs. Typically, PHCs have only one LSO that is also responsible for another health program. However, most LSOs (92 %) needed and agreed to the HIS implementation. Moreover, LSOs received leprosy control program management training (84 %) despite the fact that the training was performed after the LSOs had a rotation in the leprosy control program (Supplement 1).

Most of the LSOs (80 %) experienced difficulties in tracing patients' contact after their Release From Treatment (RFT)[7]. Some LSOs lost the documentation due to staff rotation (75 %), and LSOs should deliver MDT to patients (52 %). Moreover, 100 % of LSOs agreed that a reminder system helped them to manage patients. Furthermore, LSOs also had difficulties in infrastructure and operational finances, except for the availability of MDT (Supplement 1).

3.2. Baseline assessments

3.2.1. Characteristics of leprosy officers

The basic characteristics of LSOs were 64.3 % male and 71.4 % Diploma Degree holders. The age range of LSOs was 28–56 years old (37.8 ± 7.4), while their work experience was 3–34 years (14.1 ± 8.8). The self-perception of most LSOs regarding their internet and computer

[6] OTAs: On-time Attendances

[7] RFT: Release From Treatment

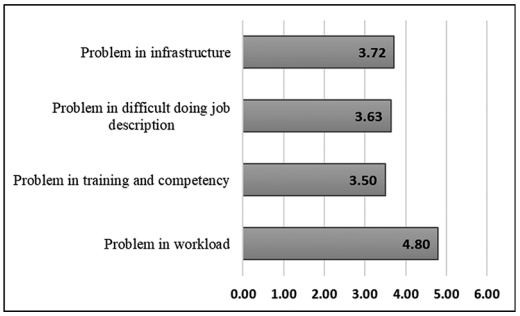

Fig. 2. Problems related to the leprosy control program at Pekalongan District based on the quantitative study.

skills was poor (> 50 %), with only 32.1 % feeling satisfied with their skill level. All of the LSOs had a mobile phone, though only 39.3 % had a smartphone. Furthermore, 71 % of LSOs did not have internet connections on their mobile phones, and 75 % never accessed the internet from their workplaces (Supplement 2).

3.2.2. Digital health literacy

3.2.2.1. Computer, email, and web fluency. The LSOs of Pekalongan District were unfamiliar with email since most of the email functions were not managed well by LSOs (> 50 %); however, their familiarity with the internet search function was sufficiently high (71.4 %) despite their low ability in using it (71.4 %). Some LSOs were unable to perform basic computer skills such as printing documents, switching a computer on, restarting a computer, and beginning new documents (range: 10–15 %) (Supplement 3).

3.2.2.2. E-health literacy. The present study used an eHeals questionnaire to measure the e-health literacy of LSOs at Pekalongan District. All of the LSO only answered a positive response so that negative options were deleted from display in Supplement 4.

We observed that the LSOs knew what and where to find health resources on the internet (> 70 %). LSOs had positive responses regarding the internet as a resource that could help them, even though > 30 % of LSOs did not have the skills necessary to evaluate and use health information from the internet (Supplement 4).

3.3. Intervention phase

3.3.1. The involvement of patients and leprosy surveillance officers

The manual registry cohort recorded 177 leprosy patients from July 1, 2014 to June 30, 2016, with 101 patients (57.6 %) being registered in the e-Leprosy program and involved in the study. The patient age range was 3–80 years old (37.3 ± 17.8), of which 67.8 % were experiencing MB leprosy. Female patients (50.8 %) were slightly higher in proportion than male patients (49.2 %). Fig. 2 presents the involvement among female leprosy patients, and MB patients being higher than that of male and PB patients, respectively.

Leprosy patients were observed in 22 of 27 of PHCs at Pekalongan District. The largest proportion of leprosy patients were registered in Buaran (20.9 %), followed by Kedungwuni 2 (9.0 %). Overall, 101 of 177 patients (57.6 %) were willing to be enrolled in the e-Leprosy framework. Notably, Bojong 2, Kajen 2, and Talun did not have any patients enrolled in this study (Supplement 5). (Fig. 3)

The manual registry cohort recorded 932 MDT drugs collection with 504 collections (54.1 %) recorded in the e-Leprosy database from the replies of LSOs. The LSOs from Bojong 1 (9.1 %), Kandangserang (8.7 %), and Wiradesa (16.7 %) had the lowest proportion of replies from MDT collections, while Siwalan (84.7 %) exhibited the highest proportion of replies. LSOs had between 1 and 37 patients (6.56 ± 7.7) patients registered in their PHCs, and the number of registered leprosy patients correlated with the involvement of LSOs ($r = 0.67$, $p < 0.01$). Notably, age, gender, and work experience did not show any correlations with the number of registered leprosy patients (Supplement 5).

3.3.2. The usability of e-Leprosy

We distributed the usability questionnaires (CSUQ) four times during the e-Leprosy intervention. Usability scores from the first to fourth distributions tended to increase during the intervention (Fig. 4). The rise of scores between the second and third distribution of questionnaires was observed as not being sufficiently high, which could be due to internet access issues during that time at Pekalongan District Health Office. Therefore, the LSOs had an overall uncomfortable experience using the e-Leprosy program.

The highest scores were observed for questions regarding the ease of finding information on patients and e-Leprosy that could help LSOs work more efficiently and productively. The lowest score was observed for the simple format of e-Leprosy. Items regarding the provided information, easy steps to learn, and satisfaction with e-Leprosy observed significant score increases between the first and fourth distributions (Supplement 6).

3.4. Evaluation of phases

3.4.1. The on-time attendances

The main outcome of this study was the proportion of OTAs among leprosy patients to receive MDT at PHCs. Table 2 presents data on the late attendance patients, which included 341 of the 1245 attendances (27.39 %) and 126 of 932 attendances (13.5 %) among before and after intervention groups, respectively. Notably, the PB type had less late patients (19.3 %) when compared to the MB type (22 %). Reminders increased OTA by 10.3 % and 14.9 % for both PB and MB patients, respectively. For total patients comparison between before and after the intervention, the increase of OTA was 13.9 % ($p < 0.01$, OR = 2.41)

3.4.2. The acceptance of leprosy

We distributed the acceptance questionnaire to 24 of 27 LSOs and one leprosy district supervisor. LSOs had varying perceptions of e-Leprosy, including classifying it as useful (100 %), likely (76 %), easy to use (72 %), and need to continue (96 %). In contrary to these facts, LSOs still encountered difficulties related to internet connections (96 %) and the format of SMS responses (76 %). Factors related to the acceptance of the e-Leprosy program included age ($r = 0.621$, $p < 0.01$) and CEW score ($r = 0.48$, $p < 0.05$) (Supplement 8).

4. Discussion

4.1. Implementation process

In the present study, we encountered difficulties in following models using the IS framework because none of the frameworks were specifically designed for eHealth [15]. IS can contribute to eHealth through measured outcomes of eHealth interventions, e.g., organizational leadership, attitudes toward innovation, and economic issues [34]. We used a comprehensive multi-level framework providing five factors representing structural, organizational, patient, provider, and innovation to evaluate the present implementation research [35].

In Indonesia, 37 % of the population are smartphone users and not everyone has mobile phone regardless of a phone subscription to 112 % of the total population, it means one person could has more than one phone numbers subscription. However, a digital divide remains between urban and rural areas. Notably, internet usage in rural Indonesia is limited due to geographical barriers and spatial inequality [36,37]. As a rural area, Pekalongan District lacks mobile phone services among PHCs, especially for internet service. Based on the baseline assessment results, we observed that not all LSOs had smartphones and mobile internet access, which affected the design of the e-Leprosy framework and influenced the adoption of SMS reminders as part of the

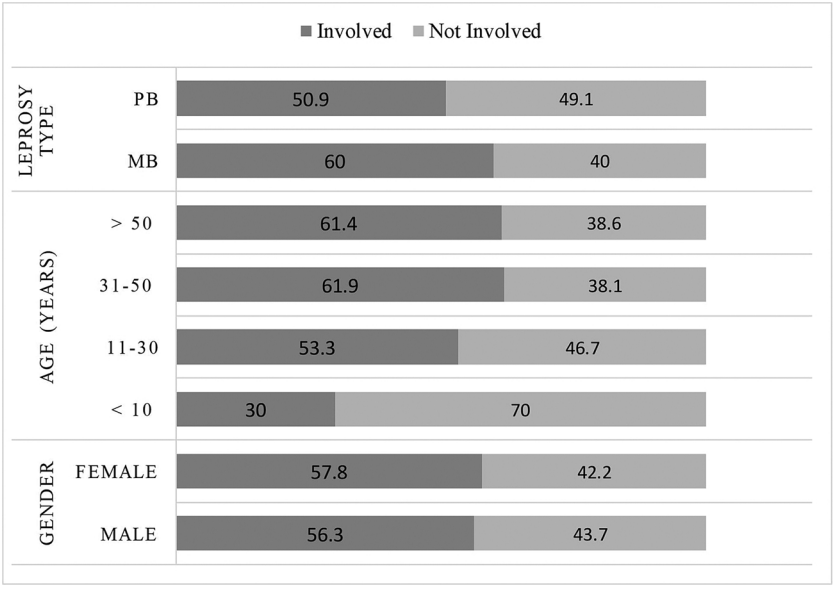

Fig. 3. The composition of patients involved in the e-Leprosy program.

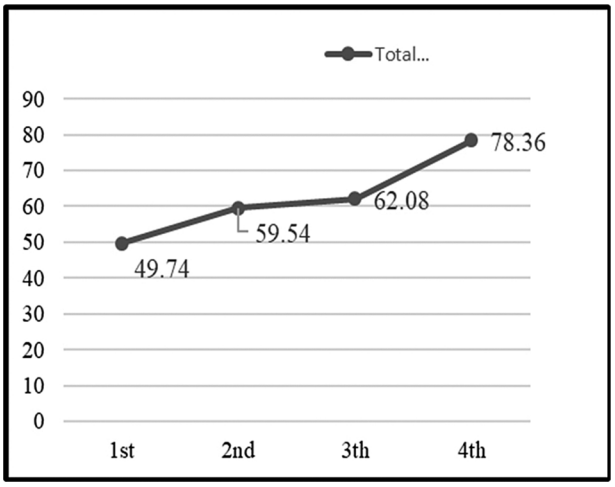

Fig. 4. e-Leprosy program usability score trends.

Table 2
The on-time attendances of leprosy patients in Pekalongan District.

Type	Attendance	Total		Before Intervention		After Intervention	
		N	%	N	%	N	%
MB	Late	385	22.0	279	28.6	106	13.7
	On time	1368	78.0	698	71.4	670	86.3
	Total	**1753**	**100.0**	**977**	**55.7**	**776**	**44.2**
PB	Late	82	19.3	62	23.1	20	12.8
	On time	342	80.7	206	76.9	136	87.2
	Total	**424**	**100.0**	**268**	**63.2**	**156**	**36.7**
Total	Late	467	21.5	341	27.4	126	13.5
	On time	1710	78.5	904	72.6	806	86.5
	Total	**2177**	**100.0**	**1245**	**57.1**	**932**	**42.8**

P = 0.0001, OR 2.413, lower 95 % CI 1.926, upper 95 % CI 3.023, PB = Paubacillary, MB = Multibacillary.

surveillance process for MDT treatments. SMS reminders have been proven to increase adherence among patients [38–40], even for the long-term use of medications [41,42].

Indonesia still faces challenges related to leprosy elimination, and this study provides strong evidence of LSOs continuing to face difficulties in conducting leprosy control programs. Moreover, several LSO job responsibilities were unable to be performed due to workload and infrastructure. However, the present study suggests that the designed e-Leprosy program with SMS notification promoted LSOs, patients, and patients' families to acknowledge the status of MDT treatment. The e-Leprosy framework involved LSOs, patients, and their relatives because the literature emphasized family support and the commitment of health providers as being critical to successful leprosy treatments [43,44].

A previous study has emphasized that the factors related to successful health information technology implementation programs include leadership, standardization, project management, and training [45]. Although the present implementation study had already collaborated with the Leprosy District Supervisor from the Pekalongan Health Office, maintaining the involvement of LSOs in the e-Leprosy program remained challenging. Although this study gained the support and commitment of the Pekalongan Health Office to integrate e-Leprosy in the routine Leprosy Control Program, the involvement of LSOs was still only 54.1 %. However, this percentage appears promising considering the positive trend of the usability scores. The rising trend in usability has demonstrated that the HIS has a great capacity to allow users to perform their tasks safely, effectively, efficiently, and enjoyably [46]. Therefore, a series of meetings and training was done from time to time to motivate LSOs to actively engage and reply to the system. This study has shown that the involvement of LSOs had a strong correlation ($r = 0.67$, $p < 0.01$) with the number of leprosy patients at their PHCs, while age, gender, and work experience did not show any significant correlations.

4.2. Outcomes

This implementation study has primary and secondary outcomes. The main outcomes describe the effect of the e-Leprosy intervention on the leprosy control program. Studies have proven that reminders can improve adherence to long-term use medications [47]. Leprosy as one of disease with long-term medication could adopt reminders to improve adherence. The present study revealed that 21.5 % of leprosy patients took medication from PHCs late and that reminders helped to increase OTA by 13.9 % ($p < 0.01$ with OR = 2.41). Furthermore, previous studies revealed that OTA decreased for MDT 3, MDT 8, and MDT 11 [42], while OTA for MDT 2 and MDT 3 related to the completed treatment of leprosy patients [48]. These facts should be considered by

the Pekalongan Health Office and LSOs since, among the defaulters, irregular consumption of MDT can cause various problems. As long as defaulters continue to live in communities and have yet to complete the full course of MDT treatment, patients remain potential sources of infection and could suffer from irreversible complications [6].

The secondary outcomes of this study were to describe factors that could affect success or failure in the adoption of the e-Leprosy program, such as digital health literacy and the acceptance of the system. Adoption of mobile health technology (m-Health) provides an opportunity to increase efficiency and productivity in health care, while the adoption and the utilization of eHealth at the PHCs correlates with human resources that are mainly related to digital health literacy. Public health informatics skills is a skill that affects the adoption of—and bridges the gap between—health and technology, which is observed to be lacking in health care facilities—especially at PHCs [49]. This study revealed that LSOs had positive perceptions regarding the e-Leprosy program despite their limitations in basic digital health literacy knowledge, especially in internet utilization. This study revealed that the acceptance of e-Leprosy had a significant relationship with the score of computer, email, and web usage ($r = 0.48$, $p < 0.05$) as well as variable age ($r = 0.621$, $p < 0.01$). Information, communication, and technology literacy education are important for health professionals to successfully adopt eHealth interventions. Notably, the limited infrastructure in rural communities is a key barrier to the potential for mobile internet to narrow the digital divide in Indonesia [50].

4.3. Strength and weakness

This implementation study has been integrated into routine practice at PHCs in Pekalongan District since the leprosy control program is managed by PHCs in Indonesia. The results of the present study could enrich the limited evidence on implementation research at PHCs since effective interventions may not always work in the real settings of local implementation programs due to limited or unpredictable transferability [11,51]. The strength of this implementation study was that it was conducted based on a population setting with the involvement of the district health office, LSOs, and volunteer patients. This comprehensive approach that observed structural, organizational, patient, provider, and innovation factors might represent the true situation of health technology interventions in Indonesian PHCs. This study was limited by not observing the attendance of patients and capturing only secondary data instead, which might lead to bias. Notably, we were only able to implement some parts of e-Leprosy—such as routine health services and the monitoring of MDT—as representative of e-Leprosy, which could be a limitation of this study.

4.4. Future research

Future studies are required to explore a cost-benefit analysis of the e-Leprosy program or related m-health projects (particularly at the regional health office levels) and the greater involvement of patients in the use of health technology.

5. Conclusion

This study demonstrated that the e-Leprosy program—a low-cost and simple technology using embedded SMS reminders—is promising for the implementation of the leprosy control program at PHCs in developing countries. The involvement of LSOs and patients remained approximately 50 %, even though the acceptance of the e-Leprosy program was higher. As such, regular meetings with LSOs could be used for training and to motivate their involvement. Important factors to consider during the implementation of this program include the digital gap, LSO workload, as well as commitment and leadership among PHCs.

Author contribution

ER, JJ, ML, CH, UI, GF, EN responsible for manuscript, ER, UI, GF responsible for analyzing data

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Ethical information

"This study has been reviewed by Review Commite of Commission on Health Research Ethics, Faculty of Public Health, Diponegoro University. Indonesia and approved by Chairman Commite Prof. Dr. dr. Suharyo Hadisaputro, SpPD (KTI) with Certificate Number 32/EC/FKM/2014″

Declaration of Conflicting Interest

The authors declare that there is no conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijmedinf.2020.104155.

References

[1] D.J. Blok, S.J. De Vlas, J.H. Richardus, Global elimination of leprosy by 2020: are we on track? Parasit. Vectors 8 (1) (2015) 1.
[2] C. Fitzpatrick, D. Engels, Leaving no one behind: a neglected tropical disease indicator and tracers for the Sustainable Development Goals, Int. Health 8 (suppl 1) (2016) i15–i18.
[3] Organization, W.H, Global Leprosy Update, 2017: Reducing the Disease Burden Due to Leprosy–situation in Weekly Epidemiological Record, (2018), pp. 445–456.
[4] L.G. Costa, D. Cortela, E. Ignotti, Factors associated with the worsening of the disability grade during leprosy treatment in Brazil, Lepr. Rev. 86 (2015) 265–272.
[5] E.R. Honrado, V. Tallo, A.C. Balis, G.P. Chan, et al., Noncompliance with the world health organization-multidrug therapy among leprosy patients in Cebu, Philippines: its causes and implications on the leprosy control program, Dermatol. Clin. 26 (2) (2008) 221–229.
[6] P. Rao, A study on non-adherence to MDT among leprosy patients, Indian J. Lepr. 80 (2) (2008) 149–154.
[7] J. Heukelbach, O.A. Chichava, A.R. de Oliveira, K. Häfner, et al., Interruption and defaulting of multidrug therapy against leprosy: population-based study in Brazil's Savannah region, PLoS Negl. Trop. Dis. 5 (5) (2011) e1031.
[8] C. Déglise, L.S. Suggs, P. Odermatt, SMS for disease control in developing countries: a systematic review of mobile health applications, J. Telemed. Telecare 18 (5) (2012) 273–281.
[9] J.G. Kahn, J.S. Yang, J.S. Kahn, Mobile'health needs and opportunities in developing countries, Health Aff. 29 (2) (2010) 252–258.
[10] WHO, Global Leprosy Strategy 2016-2020 Accelerating Towards a Leprosy-free World, in Global Leprosy, WHO SEARO/Departement of Control of Neglected Tropical Diseases, New Delhi, 2016.
[11] O. Bhattacharyya, S. Reeves, M. Zwarenstein, What is implementation research? Rationale, concepts, and practices, Res. Soc. Work Pract. 19 (5) (2009) 491–502.
[12] D.H. Peters, N.T. Tran, T. Adam, Implementation Research in Health: a Practical Guide, World Health Organization, 2013.
[13] H. Pinnock, S. Taylor, E. Epiphaniou, A. Sheikh, et al., Developing Standards for Reporting Phase IV Implementation Studies, in Protocol available from http://www. equator-network. org/wp-content/uploads/2013/09/Proposal-for-reporting-guidelines-of-Implementation-Research-StaRI. pdf. Accessed (2015).
[14] C.U. Lehmann, M. Altuwaijri, Y. Li, M.J. Ball, et al., Translational research in medical informatics or from theory to practice, Methods Inf. Med. 47 (1)

(2008) 1–3.
[15] R.E. Glasgow, S.M. Phillips, M.A. Sanchez, Implementation science approaches for integrating eHealth research into practice and policy, Int. J. Med. Inform. 83 (7) (2014) e1–e11.
[16] J. De Maeseneer, S. Willems, A. De Sutter, I. Geuchte Van de Geuchte, et al., Primary health care as a strategy for achieving equitable care: a literature review commissioned by the health systems knowledge network of CSDH, Health Systems Knowledge Network of the World Health Organization's Commission on Social Determinants of Health, (2007).
[17] J. Altmann, Observational study of behavior: sampling methods, Behaviour 49 (3) (1974) 227–266.
[18] D.H. Peters, T. Adam, O. Alonge, I.A. Agyepong, et al., Implementation research: what it is and how to do it, Bmj 347 (2013) f6753.
[19] L.A. Palinkas, G.A. Aarons, S. Horwitz, P. Chamberlain, et al., Mixed method designs in implementation research, Adm. Policy Ment. Health Ment. Health Serv. Res. 38 (1) (2011) 44–53.
[20] S. Bakken, C.M. Ruland, Translating clinical informatics interventions into routine clinical care: how can the RE-AIM framework help? J. Am. Med. Inform. Assoc. 16 (6) (2009) 889–897.
[21] R.E. Glasgow, T.M. Vogt, S.M. Boles, Evaluating the public health impact of health promotion interventions: the RE-AIM framework, Am. J. Public Health 89 (9) (1999) 1322–1327.
[22] R.G. Tabak, E.C. Khoong, D.A. Chambers, R.C. Brownson, Bridging research and practice: models for dissemination and implementation research, Am. J. Prev. Med. 43 (3) (2012) 337–350.
[23] I.D. Graham, J. Logan, M.B. Harrison, S.E. Straus, et al., Lost in knowledge translation: time for a map? J. Contin. Educ. Health Prof. 26 (1) (2006) 13–24.
[24] H. Pinnock, M. Barwick, C.R. Carpenter, S. Eldridge, et al., Standards for reporting implementation studies (StaRI) statement, Bmj 356 (2017) i6795.
[25] H. Pinnock, A. Sheikh, Standards for Reporting Implementation Studies (StaRI): Enhancing Reporting to Improve Care, Nature Publishing Group, 2017.
[26] P. Nykänen, J. Brender, J. Talmon, N. de Keizer, et al., Guideline for good evaluation practice in health informatics (GEP-HI), Int. J. Med. Inform. 80 (12) (2011) 815–827.
[27] N. De Keizer, J. Talmon, E. Ammenwerth, J. Brender, et al., Systematic prioritization of the STARE-HI reporting items, Methods Inf. Med. 51 (2) (2012) 104–111.
[28] U. Bunz, The computer-email-web (CEW) fluency scale-development and validation, Int. J. Hum. Interact. 17 (4) (2004) 479–506.
[29] C.D. Norman, H.A. Skinner, eHEALS: the eHealth literacy scale, J. Med. Internet Res. 8 (4) (2006) e27.
[30] U. Bunz, C. Curry, W. Voon, Perceived versus actual computer-email-web fluency, Comput. Human Behav. 23 (5) (2007) 2321–2344.
[31] E. Neter, E. Brainin, eHealth literacy: extending the digital divide to the realm of health information, J. Med. Internet Res. 14 (1) (2012) e19.
[32] J. R.Lewis, IBM computer usability satisfaction questionnaires:psychometric evaluation and instruction for use, Int. J. Hum. Interact. 7 (1) (1995) 57–78.
[33] E. Rachmani, C. Hsu, A. Kurniadi, How Health Information System Could Help The Leprosy Control Program in Indonesia? in International Conference On Instrumentation, Communication, Information Technology and Biomedical Engineering, (2013) Bandung, Indonesia.
[34] K. Stange, R. Glasgow, Considering and Reporting Important Contextual Factors in Research on the Patient-centered Medical Home, Agency for Healthcare Research and Quality, Rockville, MD, 2013.
[35] S.R. Chaudoir, A.G. Dugan, C.H. Barr, Measuring factors affecting implementation of health innovations: a systematic review of structural, organizational, provider, patient, and innovation level measures, Implement. Sci. 8 (1) (2013) 22.
[36] G. Hutagalung, Mo.Ca.I. Technology (Ed.), Indonesia Digital Landscape and Opportunity to Increase Competiveness, in ITU Regional Standardization Forum for Asia-Pacific, 2015 Jakarta.
[37] S. Sujarwoto, G. Tampubolon, Spatial inequality and the Internet divide in Indonesia 2010–2012, Telecomm. Policy 40 (7) (2016) 602–616.
[38] J. Car, I. Gurol-Urganci, T. de Jongh, V. Vodopivec-Jamsek, et al., Mobile Phone Messaging Reminders for Attendance at Scheduled Healthcare Appointments, The Cochrane Library, 2008.
[39] S.R. Downer, J.G. Meara, A.C. Da Costa, Use of SMS text messaging to improve outpatient attendance, Med. J. Aust. 183 (7) (2005) 366.
[40] M. Vervloet, L. van Dijk, J. Santen-Reestman, B. Van Vlijmen, et al., SMS reminders improve adherence to oral medication in type 2 diabetes patients who are real time electronically monitored, Int. J. Med. Inform. 81 (9) (2012) 594–604.
[41] S. Iribarren, S. Beck, P.F. Pearce, C. Chirico, et al., TextTB: a mixed method pilot study evaluating acceptance, feasibility, and exploring initial efficacy of a text messaging intervention to support TB treatment adherence, Tuberc. Res. Treat. 12 (2013).
[42] E. Rachmani, C.-Y. Hsu, P.W.S. Chang, J. Jumanto, et al., Encouraging on-time completion of leprosy patients treatment: implementing E-Leprosy framework to primary health care in Indonesia, Asia Pacific J. Public Health 31 (4) (2019) 296–305.
[43] M.S. Raju, A.S. John, P. Kuipers, What stops people completing multi-drug therapy? Ranked perspectives of people with leprosy, their head of family and neighbours-across four Indian states, Lepr. Rev. 86 (1) (2015) 6–20.
[44] M. Raju, M. Elkana, P. Failbus, J. Palla, et al., Correlates of defaulting from MDT among leprosy patients, Indian J. Lepr. 87 (4) (2015) 241–248.
[45] D.A. Ludwick, J. Doucette, Adopting electronic medical records in primary care: Lessons learned from health information systems implementation experience in seven countries, Int. J. Med. Inform. 78 (1) (2009) 22–31.
[46] J. Preece, Y. Rogers, H. Sharp, D. Benyon, et al., Human-computer Interaction, Addison-Wesley Longman Ltd, 1994.
[47] K.R. Mahtani, C.J. Heneghan, P.P. Glasziou, R. Perera, Reminder Packaging for Improving Adherence to Self-administered Long-term Medications, The Cochrane Library, 2011.
[48] E. Rachmani, M. Lin, C. Hsu, G.F. Shidik, et al., *Mining Medication Behavior of the Completion Leprosy's Multi-Drug Therapy in Indonesia.* in *International Seminar on Application for Technology of Information and Communication*, Semarang: IEEE, 2018.
[49] E. Rachmani, S. Anjani, N. Nurjanah, G. Fajar S, et al., Digital Health Literacy and Internet Behavior of Primary Health Care Staff in Indonesia, Are They Ready Adopting eHealth?, in the 3rd Faculty of Public Health Universitas Indonesia Science Festival: Public Health Challenges Towards Disruptive Technology, FKM UI: Jakarta, 2019.
[50] K. Onitsuka, A.R.T. Hidayat, W. Huang, Challenges for the next level of digital divide in rural Indonesian communities, Electron. J. Inf. Syst. Dev. Ctries. 84 (2) (2018) e12021.
[51] R. Foy, M. Eccles, J. Grimshaw, Why Does Primary Care Need More Implementation Research? Oxford University Press, 2001.