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User experience analysis of an eHealth system for tuberculosis in resource-constrained settings: A nine-country comparison

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ABSTRACT

Background: e-TB Manager, a web-based eHealth system has been successfully institutionalized in 10 resource-constrained countries that account for one-third of the world's tuberculosis (TB) burden, but user experience has never been evaluated.

Methods: A cross-sectional, anonymous survey in eight unique languages based on the targeted countries. e-TB Manager users included nurses, doctors, pharmacists, statisticians/data officers, laboratory professionals/assistants, health workers, and administrators.

Results: With an 86.3% completion rate for all required questions, 1,511 completed responses were analyzed. Users had worked in TB programs for a median of five years and had used e-TB Manager for a median of two years. Overall, 60.2% of respondents were female, 65% were clustered in the age groups of 30–39 and 40–49 years old, and nearly half (49%) were using e-TB Manager at the district and sub-district levels of a country's health system. Older respondents aged over 50, regardless of location and with at least 6 or more years of experience in public-sector TB programs, had higher mean satisfaction scores than did their younger counterparts. Overall, those who had used e-TB Manager for more than two years had significantly higher mean scores for the majority of the survey statements than did those who had used e-TB Manager for less than two years. Ukraine had significantly higher mean scores for finding patient information available in e-TB Manager and in its benefit in improving patient care compared to Brazil, Armenia, Nigeria, and Indonesia. Brazil and Ukraine differed significantly from five other countries in that they did not need additional training, thereby demonstrating their institutional capacity after more than five years of using e-TB Manager.

Conclusion: Although users gave high ratings to e-TB Manager in terms of helping to improve patient care, found it to be reliable, and were generally satisfied, there is need for a combination of refresher training and e-learning methodologies to keep pace with programmatic changes

1. Introduction

The 2016 World Health Assembly's high-level, inter-ministerial roundtable acknowledged that digital health technologies, such as eHealth and mHealth are important to help achieve sustainable development goals including universal health coverage [1]. Digital health technologies are resource intensive and require a combination of capital, trained human resources, infrastructure upgrades, and funding for their maintenance [2]. A systematic review of electronic health record implementation in resource-constrained settings found that technical aspects, training programs, and infrastructure support all influence the effective use of the system, particularly in the more than half of reviewed projects that were donor funded [3]. Donors such as the United States Government and the Global Fund to fight AIDS, Tuberculosis and Malaria (Global Fund) are committed to funding digital health technologies and quality information systems that will promote better patient care and build resilient and sustainable health systems [4,5]. The Sustainable Development Goal 3 call for ending the tuberculosis (TB) epidemic by 2030, and the Global Plan to Stop TB makes the case for investing in digital patient information systems in various country and regional settings [6]. The World Health Organization's (WHO) digital health for the End TB strategy calls for applying digital health solutions to help advance patient care and improve surveillance and

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program management [7]. In particular, the use of digital health applications to manage multi-drug resistant TB (MDR-TB), a public health crisis is needed to help improve the accuracy of reporting on treatment outcomes [8]. Of the 30 high-burden MDR-TB countries, 23 reported using national electronic databases, and all TB patients were covered in 16 of those countries [9].

One web-based electronic database is e-TB Manager, which manages all information needed by public-sector national TB control programs under the authority of a country's Ministry of Health. It integrates data across all aspects of TB control, including information on suspects, patients, medicines, laboratory testing, diagnosis, treatment, and outcome [10]. First developed and implemented in Brazil in 2004, e-TB Manager is currently operating in over 1,600 active sites in 10 countries and managing more than half a million TB cases, MDR-TB cases, and presumptive TB individuals. e-TB Manager was implemented through multi-year serial global projects with seed funding from the United States Agency for International Development (USAID). Subsequently, country authorities sought additional funding from the Global Fund and mobilized resources from country health budgets for the continued implementation or expansion of e-TB Manager. At the country level, several stakeholders and partners were involved during piloting and implementation, particularly in the areas of user training programs, infrastructure support, and technology updates, while scaling up WHO recommended programmatic management of MDR-TB. e-TB Manager has been formally handed over to government authorities in nine of the 10 implementing countries and is used as part of TB surveillance, patient care from diagnosis to medication adherence, monitor treatment outcomes and manage medicines and diagnostics supplies.

While our project obtained serial feedback from users and national decision makers on their experience during e-TB Manager adoption and pilot phase to inform implementation strategies, no systematic user experience evaluation has been performed in any country after e-TB Manager's nationwide implementation. Some of the implementing countries are characterized by high turnover of trained users; the gradual withdrawal of donor funding and/or international technical assistance; and continued challenges in infrastructure support, such as need for computer upgrades, sporadic internet access, and interrupted electricity. In addition, e-TB Manager has not yet entirely replaced paper-based recording and reporting systems. An evaluation of the e-TB Manager user experience was deemed important to inform national authorities, donors and international technical agencies on future directions for e-TB Manager as a digital health application for WHO's End TB strategy [11,12]. The goal was to assess user experience with e-TB Manager as part of users' responsibilities in national TB control programs (NTPs) in 10 implemented countries. The specific objectives were to compare user experience: 1) by years of experience working in an NTP and using e-TB Manager; 2) by age and location; and 3) among individual countries.

2. Methods

2.1. Survey development

An adapted version of a survey to evaluate the Open Medical Record System (MRS) was utilized due to the instrument's suitability for resource-constrained settings [13]. The adapted 12-item survey was prepared by NK for internal team review for content and face validity. A multi-stage Delphi consensus method was applied to produce the final version of the survey. Two e-TB Manager subject matter experts provided feedback on the choice of words for clarity, particularly because the survey was to be administered in eight unique languages in eight countries and in English for two countries. We changed the Likert scale from the original survey to range from strongly disagree to strongly agree but retained the 0–7 scale. Over the last 10 years, our predecessor projects, international technical partners, and country TB programs have conducted training programs and orientation efforts to ensure that users and decision makers at varying levels of the health system have both knowledge and skills on the various features of e-TB Manager, such as case management, medicine supply management, report generation, and administration. To assess this, we introduced a new question, "*I have the required capacity to use all features of e-TB Manager linked to my responsibilities*" and made adjustments to five questions relevant to e-TB Manager. In addition, we ensured that the adapted English version was sufficiently clear for ease of translation into other languages for non-English speaking countries. We created six questions on user characteristics and demographics and added an open text box to enable users to share any feedback or suggestions (Appendix A).

Because e-TB Manager users such as nurses, doctors, pharmacists, statisticians/data officers, laboratory professionals/assistants, health workers and administrators in our target countries tend to have high workloads and significant data entry burdens, our intent was to have users complete the survey in the range of 5–10 min. We went through a second round of questionnaire review that included three additional colleagues who had provided technical assistance on e-TB Manager in resource-constrained countries. Further modifications were made to the wording, sequence of questions, and verification for face and content validity, and the survey was shortened until consensus was achieved. Subsequently, we invited our e-TB Manager focal project staff based in Namibia to review the revised questionnaire for content validity, clarity of wording, and length of time needed to complete the survey. No further changes were made based on this review.

2.2. Survey administration portal

Because we intended to administer the survey through an online mechanism, KS reviewed the comparative features and benefits of Google Forms, Survey Monkey, and Survey Gizmo. We selected Survey Gizmo's paid service due to its ability to efficiently create and administer the survey, its data management features and data analysis capabilities, and its reporting functions. Moreover, this portal had an excellent interface to administer non-English language surveys, which was one of our main requirements. Survey Gizmo is compatible with any device (e.g., smartphones, tablets, computers), which allows users to complete the survey from any platform. After learning that we could use Survey Gizmo's logic features to probe why a respondent chose a particular response, we further modified our adapted 12-item questionnaire. We added logic for the questions on perceived satisfaction with and reliability of e-TB Manager and on the adequacy of e-TB Manager training. If a respondent chose 0, 1, or 2 on the left end of the scale for the range of disagreement, Survey Gizmo would show an additional question only to this subset of respondents. In the additional question, we asked the respondent to explain why a low rating was chosen and offered a list of choices based on our programmatic experience (Appendix A). With six demographic and user characteristic questions and 12 core questions, the total length of the survey was a minimum of 18 questions and could increase to 21 questions if the user chose a rating of 0, 1, or 2 for the three logic-based questions.

The survey was designed to be anonymous, and no respondent identifiers, such as the name of the health facility or the user's email addresses, were tracked or collected. Initially, responses to all survey questions were required, and if a user skipped a question and clicked the next page button, Survey Gizmo would prompt the user to complete the required question. We eliminated this requirement for the question on e-TB Manager level of use and location of the

Table 1
Participating countries.

Country	e-TB Manager year of introduction[a]	Survey language	Supporting project for survey	Approval provided by
Armenia	2009	Armenian	USAID-funded Systems for Improved Access to Pharmaceuticals and Services (SIAPS) Program, administered by Management Sciences for Health (MSH)	NTP Director
Azerbaijan	2008	Azeri	USAID SIAPS Program, MSH	N/A
Bangladesh	2010	Bangla	USAID SIAPS Program, MSH	NTP Director
Brazil	2004	Portuguese	USAID SIAPS Program, MSH	Health Surveillance Secretariat, NTP
Cambodia	2011	Khmer	USAID Health Information Policy and Advocacy Project, Palladium Group	NTP Director
Indonesia	2009	Bahasa Indonesia	USAID Challenge TB Project, KNCV Tuberculosis Foundation	NTP Director
Namibia	2010	English	USAID SIAPS Program, MSH	MDR-TB Advisor
Nigeria	2011	English	USAID SIAPS Program, MSH, and USAID Challenge TB Project, KNCV Tuberculosis Foundation	Assistant NTP Director
Ukraine	2009	Ukrainian	USAID SIAPS Program, MSH	NTP Director
Vietnam	2011	Vietnamese	USAID SIAPS Program, MSH, and USAID Challenge TB Project, KNCV Tuberculosis Foundation	NTP Director

[a] After a year of introduction, there was a pilot phase of at least two years, depending on each country context, before the scale-up process began.

user (i.e., central/national, province/state, or district/sub-district) in case the respondent did not wish to indicate his or her primary work location. This meant there were 17 required questions and one optional demographic question.

2.3. Institutional permission

The anonymous user experience survey was part of our ongoing programmatic monitoring and evaluation efforts of existing donor-approved e-TB Manager-related project workplans, which are conducted in collaboration with country government authorities and their local technical partners. We sought formal permission from the relevant government authority in a country's NTP either directly or through our partner project in-country (Table 1) and was conducted according to principles of the Declaration of Helsinki [14].

Of the 10 countries using e-TB Manager, we obtained approval from all except Azerbaijan, which opted out of the survey. Each NTP director received the request in writing along with a copy of the survey. In some cases, the survey needed to be translated before beginning the approval process. The written request explained the survey administration methodology and how user experience feedback could inform ongoing quality improvement efforts. Any subsequent questions or clarification needed by the country authority were addressed through either face-to-face meetings with our personnel or project partners on the ground.

2.4. Survey translation verification and administration process

As shown in Table 1, seven of the nine participating countries required that the survey be translated into the local language. The translation was primarily performed by either the project staff or NTP program staff. Any questions related to an English word or phrase during translation were resolved via email, phone calls, or in person, depending on the country. For each of the seven countries where the survey was to be administered in a local language, we sought translation verification by at least two persons familiar with both English and use of e-TB Manager in the given country. Any needed modifications to the translated text were made, and the final version was sent back to the survey team lead (NK). The translated survey was then loaded into Survey Gizmo for the given country. The dedicated country web hyperlink of the survey was sent to the country focal person to verify that the translated survey was loaded accurately. Each country was asked to test the web survey version using dummy data and report back if there were any errors. A sample cover note was provided for adaptation and translation for the NTP Director or designate at the country level to disseminate the survey invitation, which assured users of the anonymity of their response.

The survey administration period varied depending on when approval was received, with all surveys conducted between September 2015 and July 2016. In collaboration with the country NTP, we used a range of methods to disseminate the survey, starting with email dissemination (Appendix B, table B1). In some countries, email was not effective, and we subsequently sent the survey invitation through e-TB Manager's system dialogue box, which is seen after the user logs into the system. At least one reminder was sent in each country, and additional follow-up phone calls to state or regional supervisors in some countries were made. All responses were recorded in Survey Gizmo and only one author (NK) had access to maintain the anonymity and confidentiality of the responses.

2.5. Data analysis

Our hypothesis was that years of experience using e-TB Manager and years of experience working in the NTP could influence user experience as reflected in mean scores for the dependent variables (12 core questions). If one is not knowledgeable with programmatic and clinical management of MDR-TB and its associated recording and reporting procedures necessary for both paper-based systems and electronic applications, the job can be difficult [15,16]. Therefore, we compared the mean scores of the core questions among user groups by categories based on years of experience using e-TB Manager, years working in the NTP, age, and location. We used *t*-test to compare the mean scores among two groups of users and analysis of variance (ANOVA) to compare more than two groups with Tukey's post-hoc test. We also investigated three-way interactions and provided effect size values [17]. For the third objective on comparing mean scores for all nine countries, ANOVA was performed using Scheffe's procedure, the conservative post-hoc test [18]. Statistical analysis was performed using SPSS package, version 22 (SPSS Inc., Chicago, IL, USA). Only completed responses for all required questions were utilized for the statistical analysis.

Table 2
Years working in National TB Program and Years using e-TB Manager.

	Armenia (n = 68)	Bangladesh (n = 220)	Brazil (n = 431)	Cambodia (n = 32)	Indonesia (n = 176)	Namibia (n = 38)	Nigeria (n = 150)	Ukraine (n = 303)	Vietnam (n = 93)	All countries (n = 1,511)
Number of years working in National TB Program										
Mean	9.1	10.5	8.3	8.8	4.6	5.9	8.0	7.1	7.7	7.8
Median	7.0	8.0	5.0	2.5	4.0	5.0	6.0	4.0	5.0	5.0
Std Dev	8.4	8.4	7.7	10.1	3.7	3.6	6.3	6.7	7.4	7.3
Min	1.0	0.5	0.5	1.0	0.3	0.5	1.0	1.0	1.0	0.3
Max	44	37	44	34	22	14	30	37	33	44
Number of years using e-TB Manager										
Mean	2.3	2.3	2.8	1.6	2.1	2.1	2.0	2.7	2.0	2.4
Median	2.0	2.0	2.0	1.0	2.0	2.0	2.0	3.0	2.0	2.0
Std Dev	0.8	1.3	1.8	0.9	1.3	1.4	1.3	1.2	1.2	1.4
Min	0.5	0.5	0.5	1.0	0.3	0.5	0.5	0.5	1.0	0.3
Max	4.0	6.0	8.0	4.0	7.0	6.0	6.0	6.0	6.0	8.0

3. Results

3.1. Response rates

We received 1,751 responses from 2,146 individuals who were active users of e-TB Manager at the time the cross-sectional survey was conducted, representing an initial response rate of 81.6%. Of the 1,751 responses, there were 240 partial responses, resulting in an 86.3% completion rate (n = 1,511) for all required questions. Among the nine countries, the median effective response rate was 77.1%, and the average was 73.3%. Appendix B lists the methods for calculating the response rate and the specific duration of the survey administration in each country [19]. The cronbach's alpha for our 12 core questions was 0.82, indicating high internal consistency of our adapted questionnaire. Without the two reverse worded questions, the cronbach's alpha was 0.86 for the remaining ten questions.

3.2. Characteristics of respondents

Among the nine countries, users reported working in the NTP for a median of five years (M = 7.8 years, SD = 7.3). Table 2 provides similar information for each country along with a box-and-whisker diagram (Fig. 1). Overall, users reported using e-TB Manager for a median of two years (M = 2.4 years, SD = 1.4). Females comprised at least 60% of the proportion of respondents in Armenia, Brazil, Indonesia, Namibia, and Ukraine (Fig. 2). Vietnam and Indonesia had the highest proportions (70% or more) of respondents under the age of 40. In Armenia, Brazil, Namibia, and Nigeria, at least 60% of users were over the age of 40 (Fig. 3). Across the nine countries, nearly half (49%) of respondents were at the district or sub-district level, followed by 40.8% at the state, province, or regional level and 8% at the central or national level (Fig. 4). Thirty-three respondents (2.2%) did not answer this optional question. The proportion of users at the district or sub-district level in a country's health system was highest in Bangladesh (89.5%), followed by Ukraine (71%) and Namibia (68.4%). The highest proportions of respondents at the province level were in Armenia (70.6%) and Vietnam (67.7%).

3.3. Comparison of responses by user characteristics

3.3.1. Years of experience using e-TB Manager and working in NTP

Overall, those who had used e-TB Manager for more than two years had significantly higher mean scores for all but two reverse-worded questions than did those who had used e-TB Manager for two years or less (Table 3). Respondents with less than three years of experience had significantly lower mean scores for perceived capacity of using all features of e-TB Manager linked to their specific responsibilities and adequacy of training received compared to all other users with progressively more years of experience working in an NTP (Table 4). Users with more than 11 years of experience working in an NTP had significantly higher mean scores for nine of twelve questions compared to users with less than three years of experience. Regardless of years of experience working in the NTP, there was no significant difference in mean scores for improved workplace productivity associated with using e-TB Manager.

3.3.2. Age

There were no significant differences among age groups on the perceived capacity of using e-TB Manager (Table 5). However, younger users (18–29) had significantly lower mean scores for the statement, "I do not need more training on e-TB Manager" compared to users aged 30–39 ($p < 0.05$), 40–49 ($p < 0.05$), and over 50 ($p < 0.00$). Users aged over 50 showed significant differences compared to their younger counterparts in the three age categories. They had significantly higher mean scores compared to users aged 18–29 ($p < 0.00$) and 40–49 ($p < 0.01$) regarding adequacy of training received and significantly higher mean scores compared to users aged 18–29 regarding the support and infrastructure received for e-TB Manager ($p < 0.05$). They also differed significantly from users aged 30–39 ($p < 0.05$) on the statement, "e-TB Manager does not help me identify errors or inaccuracies in patient's files."

3.3.3. Location

There were variations in mean scores for the 12 core questions depending on the user-reported location (Table 6). Users at the district level differed significantly from those at the central ($p < 0.05$) and province ($p < 0.00$) levels in their belief that the information needed for case management is available in e-TB Manager. Compared to province-level users, those at the district level had significantly higher satisfaction ($p < 0.05$), workplace productivity ($p < 0.05$), and perceived reliability ($p < 0.00$). While there were no significant differences for user location on perceived capacity and adequacy of training received, both province- ($p < 0.00$) and district-level ($p < 0.01$) users differed significantly from central-level users on the statement, "I do not need more training on e-TB Manager."

3.3.4. Three-way interaction

3.3.4.1. Years using e-TB Manager, age and location. While there were main effects for the dependent variables and predominantly significant two-way interactions, the effect size, as expressed in η^2, was small (Table 7). There was a three-way interaction for age*location*years using e-TB Manager on the belief that generating reports from paper systems is faster than e-TB Manager. No other three-way interaction was significant. There were significant two-way interactions for location*years using e-TB Manager for satisfaction (Q1), not needing more training (Q3), not taking long to

Table 3
Comparison of responses by years using e-TB Manager (Mean, SD).

	Total (n = 1,511)	2 years or less (n = 860)	More than 2 years (n = 651)	p value
Q1: I am satisfied with e-TB Manager	5.43 (1.55)	5.31 (1.61)	5.58 (1.47)**	p = 0.001
Q2: I have the required capacity to use all features of e-TB Manager linked to my responsibilities	5.35 (1.62)	5.08 (1.71)	5.71 (1.43)***	p = 0.000
Q3: I do not need more training on e-TB Manager	3.15 (2.45)	2.86 (2.41)***	3.53 (2.44)	p = 0.000
Q4: I am happy with the available support and infrastructure for e-TB Manager	4.84 (1.88)	4.76 (1.90)	4.96 (1.85)*	p = 0.037
Q5: It does not take me long to enter or find information in e-TB Manager	5.17 (1.79)	5.02 (1.86)	5.36 (1.67)***	p = 0.000
Q6: e-TB Manager helps me to improve case management	5.70 (1.55)	5.59 (1.57)	5.84 (1.51)**	p = 0.003
Q7: The training I received on e-TB Manager is adequate	4.22 (2.25)	3.82 (2.31)	4.75 (2.06)***	p = 0.000
Q8: The information needed for case management is available in e-TB Manager	5.47 (1.50)	5.34 (1.51)	5.65 (1.45)***	p = 0.000
Q9: Generating reports from the paper system is faster than e-TB Manager[a]	2.54 (2.39)	2.60 (2.37)	2.46 (2.41)	
Q10: e-TB Manager does not help me identify errors or inaccuracies in patient files[a]	2.72 (2.32)	2.70 (2.29)	2.75 (2.37)	
Q11: My workplace productivity has improved because of e-TB Manager	5.08 (1.85)	4.95 (1.85)	5.25 (1.83)**	p = 0.002
Q12: e-TB Manager is reliable	5.62 (1.55)	5.50 (1.60)	5.79 (1.47)***	p = 0.000

*p < 0.05.
**p < 0.01.
***p < 0.00.
[a] Reverse worded questions.

Table 4
Comparison of responses by number of years worked in National TB program (Mean, SD).

	Total (n = 1,511)	① Less than 3 years (n = 365)	② 3–5 years (n = 443)	③ 6–10 years (n = 323)	④ Over 11 years (n = 380)	Post-hoc test
Q1: Satisfaction	5.43 (1.55)	5.20 (1.65)	5.38 (1.61)	5.44 (1.55)	5.68 (1.35)	④ > ①***, p = 0.000
Q2: Have capacity	5.35 (1.62)	4.93 (1.77)	5.45 (1.60)	5.51 (1.55)	5.50 (1.52)	② > ①***, p = 0.000 ③ > ①***, p = 0.000 ④ > ①***, p = 0.000
Q3: Do not need more training	3.15 (2.45)	2.83 (2.44)	3.13 (2.43)	3.25 (2.43)	3.39 (2.47)	④ > ①*, p = 0.011
Q4: Support and infrastructure	4.84 (1.88)	4.62 (1.88)	4.73 (1.90)	4.94 (1.89)	5.11 (1.83)	④ > ①**, p = 0.002 ④ > ②*, p = 0.019
Q5: Enter or find information	5.17 (1.79)	4.99 (1.79)	5.14 (1.82)	5.22 (1.79)	5.34 (1.74)	④ > ①*, p = 0.04
Q6: Case management	5.70 (1.55)	5.46 (1.680	5.66 (1.58)	5.78 (1.55)	5.90 (1.34)	④ > ①**, p = 0.001 ③ > ①*, p = 0.032
Q7: Training is adequate	4.22 (2.25)	3.55 (2.29)	4.40 (2.14)	4.76 (2.07)	4.20 (2.33)	② > ①***, p = 0.000 ③ > ①***, p = 0.000 ④ > ①***, p = 0.000
Q8: Information is available	5.47 (1.50)	5.30 (1.52)	5.49 (1.51)	5.47 (1.50)	5.63 (1.44)	④ > ①*, p = 0.013
Q9: Paper system is faster [a]	2.54 (2.39)	2.77 (2.41)	2.58 (2.38)	2.44 (2.27)	2.36 (2.47)	
Q10: Errors or inaccuracies [a]	2.72 (2.32)	3.04 (2.34)	2.80 (2.36)	2.62 (2.17)	2.40 (2.36)	④ < ①**, p = 0.001
Q11: Workplace productivity	5.08 (1.85)	4.91 (1.80)	5.09 (1.88)	5.05 (1.88)	5.25 (1.83)	
Q12: Reliable	5.62 (1.55)	5.49 (1.480	5.63 (1.51)	5.58 (1.66)	5.78 (1.58)	④ > ①*, p = 0.049

*p < 0.05.
**p < 0.01.
***p < 0.00; Tukey's HSD.
[a] Reverse worded question.

Table 5
Comparison of responses by age categories (Mean, SD).

	Total (n = 1,511)	① 18–29 years (n = 187)	② 30–39 years (n = 502)	③ 40–49 years (n = 496)	④ 50+ years (n = 326)	Post-hoc test
Q1: Satisfaction	5.43 (1.55)	5.29 (1.74)	5.35 (1.51)	5.49 (1.55)	5.52 (1.51)	
Q2: Have capacity	5.35 (1.62)	5.22 (1.78)	5.29 (1.57)	5.39 (1.67)	5.45 (1.55)	
Q3: Do not need more training	3.15 (2.45)	2.56 (2.37)	3.20 (2.44)	3.13 (2.51)	3.45 (2.35)	② > ①*, p = 0.012 ③ > ①*, p = 0.036 ④ > ①***, p = 0.000
Q4: Support and infrastructure	4.84 (1.88)	4.61 (2.03)	4.75 (1.75)	4.88 (1.97)	5.07 (1.83)	④ > ①*, p = 0.04
Q5: Enter or find information	5.17 (1.79)	5.08 (1.94)	5.14 (1.75)	5.14 (1.83)	5.31 (1.68)	
Q6: Case management	5.70 (1.55)	5.68 (1.64)	5.60 (1.51)	5.75 (1.52)	5.78 (1.59)	
Q7: Training is adequate	4.22 (2.25)	3.71 (2.35)	4.28 (2.17)	4.06 (2.32)	4.67 (2.10)	④ > ①***, p = 0.000 ④ > ③**, p = 0.001 ② > ①*, p = 0.016
Q8: Information is available	5.47 (1.50)	5.41 (1.62)	5.42 (1.40)	5.53 (1.54)	5.51 (1.50)	
Q9: Paper system is faster [a]	2.54 (2.39)	2.67 (2.56)	2.68 (2.31)	2.30 (2.35)	2.60 (2.45)	
Q10: Errors or inaccuracies [a]	2.72 (2.32)	2.71 (2.40)	2.93 (2.27)	2.66 (2.38)	2.49 (2.24)	④ < ②*, p = 0.043
Q11: Workplace productivity	5.08 (1.85)	5.12 (1.84)	4.97 (1.80)	5.14 (1.91)	5.13 (1.83)	
Q12: Reliable	5.62 (1.55)	5.53 (1.63)	5.48 (1.55)	5.73 (1.52)	5.73 (1.54)	

*p < 0.05.
**p < 0.01.
***p < 0.00; Tukey's HSD.
[a] Reverse worded questions.

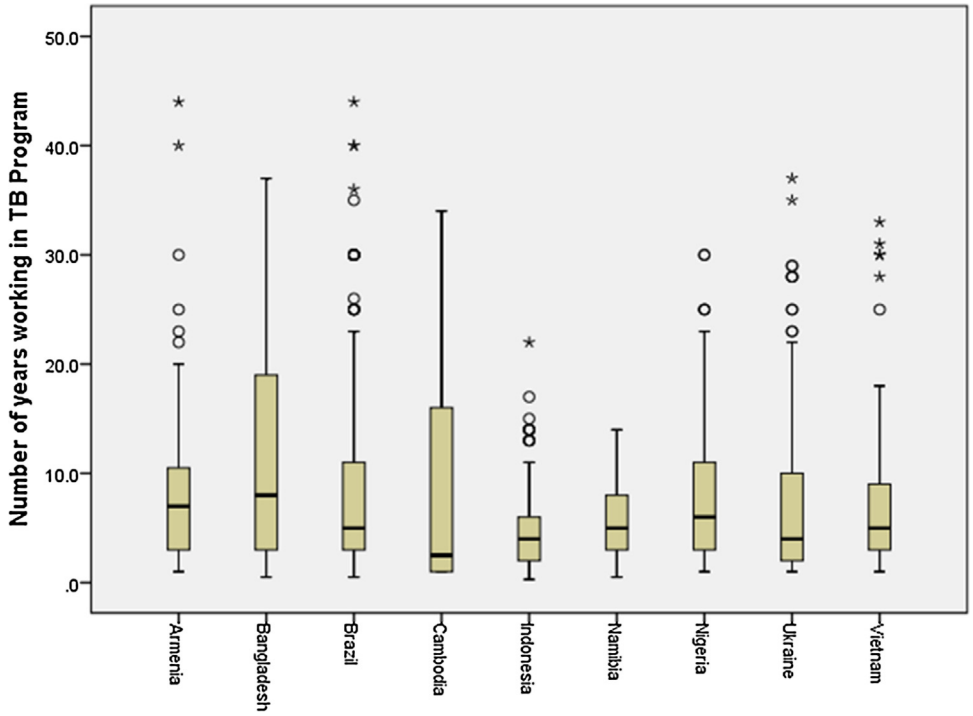

Fig. 1. Number of years working in TB program.

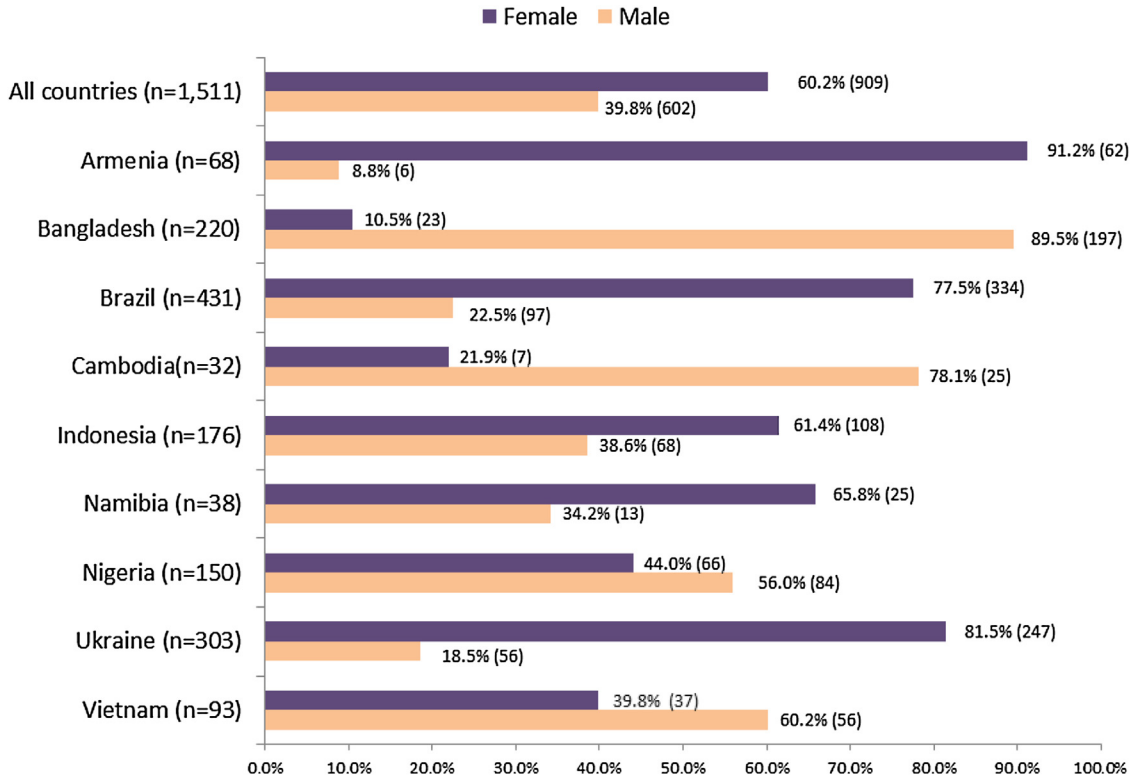

Fig. 2. Gender of e-TB Manager users.

enter or find information in e-TB Manager (Q5) and improved case management due to e-TB Manager (Q6). Respondents who had used e-TB Manager for two years or less and were at the district level had relatively higher satisfaction scores (M = 5.41, SD = 1.67) than did users located at the province (M = 5.28, SD = 1.46) and central (M = 4.78, SD = 1.95) levels who had also used e-TB Manager for less than two years. Respondents who had used e-TB Manager for more than two years and were located at the central (M = 5.88, SD = 1.14) and district (M = 5.52, SD = 1.57) levels had relatively higher mean scores for not taking long to enter or find information compared to province-level users (M = 5.09, SD = 1.81). Within the central level, respondents who had used e-TB Manager for more than two years

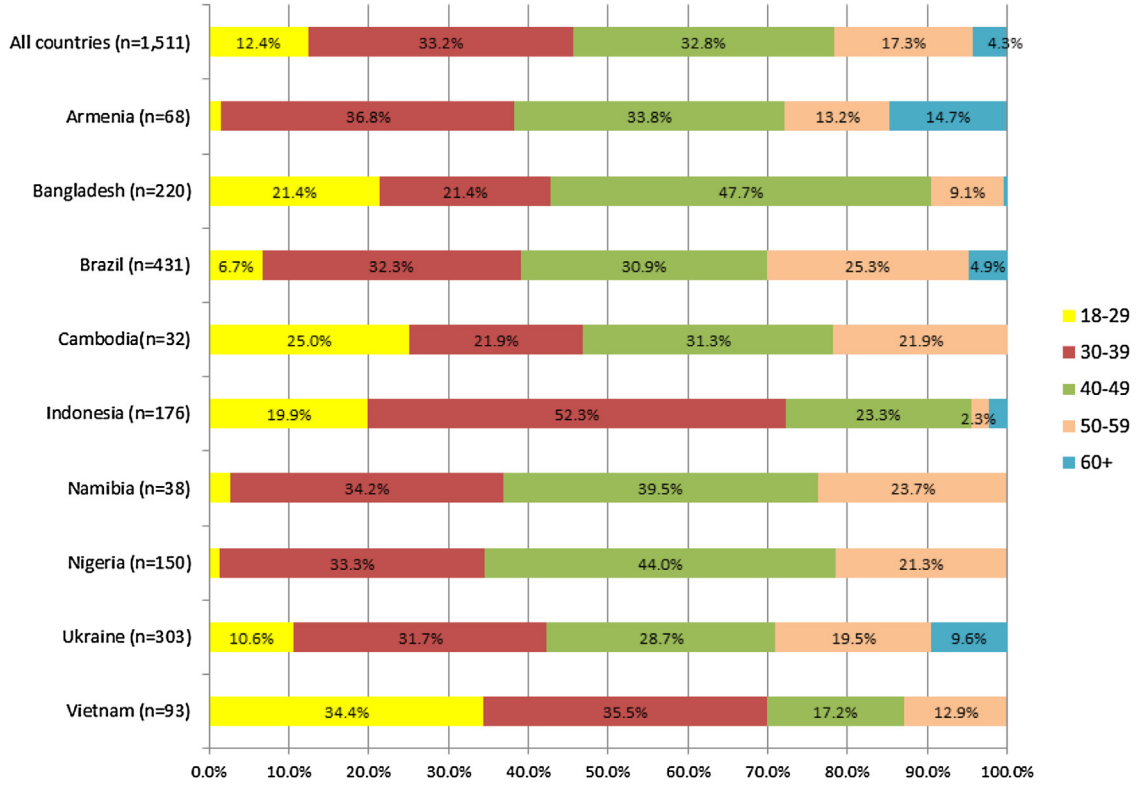

Fig. 3. Age of e-TB Manager users.

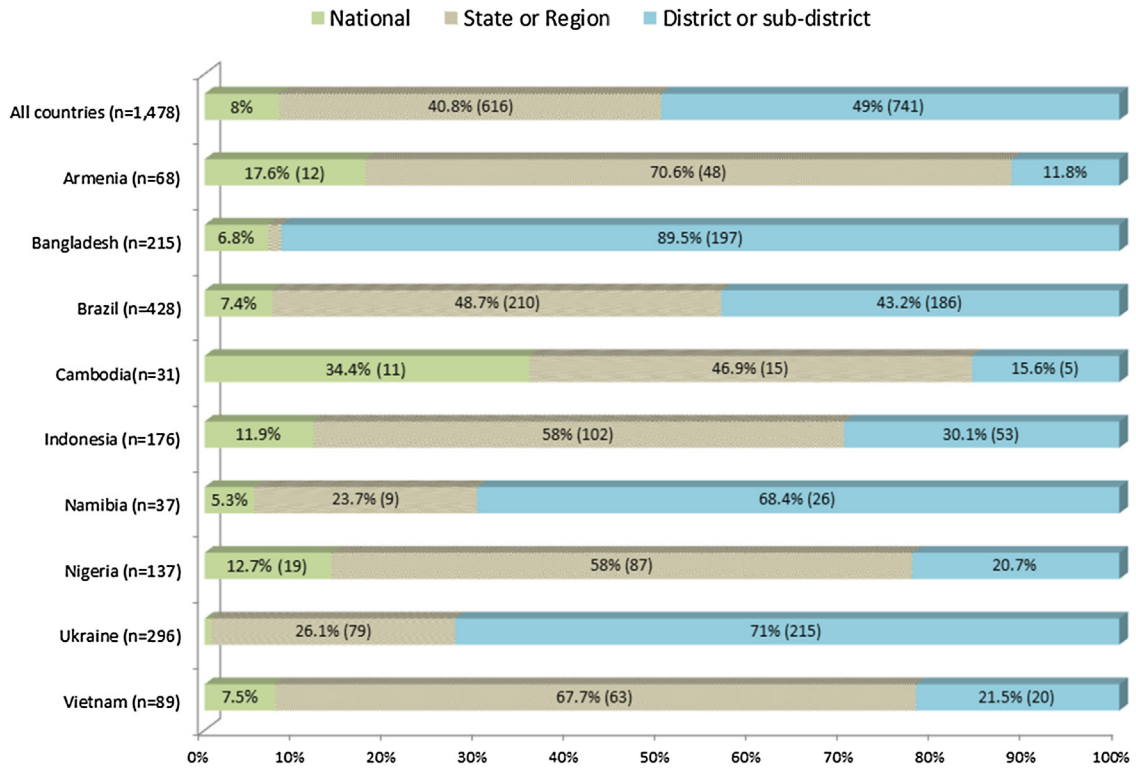

Fig. 4. Location of e-TB Manager users.

had higher mean scores (M = 6.29, SD = 0.93) than those who had used it for less than two years (M = 5.33, SD = 1.51) for e-TB Manager's help in improving case management.

3.3.4.2. Years working in NTP, age and location. There were main effects for all but three questions (except Q1, Q9, Q11) with small effect size. There was a three-way interaction for

Table 6
Comparison of responses by location of user (Mean, SD).

	Total (n = 1,478)	① Central (n = 121)	② Province/ Region/State (n = 616)	③ District and sub-district (n = 741)	Post-hoc test
Q1: Satisfaction	5.43 (1.55)	5.31 (1.68)	5.31 (1.53)	5.54 (1.56)	③ > ②, $p^{*} = 0.021$
Q2: Have capacity	5.37 (1.61)	5.55 (1.41)	5.34 (1.57)	5.37 (1.68)	
Q3: Do not need more training	3.16 (2.45)	3.92 (2.29)	2.96 (2.37)	3.19 (2.51)	① > ②, $p^{***} = 0.000$ ① > ③, $p^{**} = 0.007$
Q4: Support and infrastructure	4.85 (1.89)	5.07 (1.68)	4.71 (1.88)	4.92 (1.92)	
Q5: Enter or find information	5.18 (1.78)	5.45 (1.58)	5.05 (1.75)	5.24 (1.84)	
Q6: Case management	5.70 (1.55)	5.79 (1.35)	5.58 (1.56)	5.78 (1.56)	
Q7: Training is adequate	4.23 (2.25)	4.57 (1.86)	4.32 (2.16)	4.10 (2.38)	
Q8: Information is available	5.48 (1.50)	5.28 (1.47)	5.31 (1.47)	5.65 (1.50)	③ > ①, $p^{*} = 0.033$ ③ > ②, $p^{***} = 0.000$
Q9: Paper system is faster [a]	2.54 (2.39)	2.18 (2.22)	2.58 (2.34)	2.57 (2.47)	
Q10: Errors or inaccuracies [a]	2.71 (2.32)	2.19 (2.06)	2.70 (2.23)	2.81 (2.42)	③ < ①, $p^{*} = 0.017$
Q11: Workplace productivity	5.07 (1.86)	5.22 (1.74)	4.89 (1.81)	5.19 (1.90)	③ > ②, $p^{*} = 0.011$
Q12: Reliable	5.62 (1.56)	5.49 (1.53)	5.45 (1.62)	5.78 (1.50)	③ > ②, $p^{***} = 0.000$

$^{*}p < 0.05$.
$^{**}p < 0.01$.
$^{***}p < 0.00$; Tukey's HSD.
[a] Reverse worded questions.

Table 7
Findings of three-way ANOVA for years using e-TB Manager and years working in NTP, each with age and location.

Item	Years using e-TB Manager*age*location	Years working in NTP*age*location
Q1: Satisfaction	Main effect for years using e-TB Manager $F(1, 1454) = 14.22$, $p < 0.00$, $\eta^2 = 0.01$ age*location: $F(6, 1454) = 2.41$, $p < 0.05$, $\eta^2 = 0.01$ location*e-TB Manager: $F(2, 1454) = 4.38$, $p < 0.05$, $\eta^2 = 0.01$	age*location: $F(6, 1433) = 2.19$, $p < 0.05$, $\eta^2 = 0.01$ age*NTP: $F(9, 1433) = 2.11$, $p < 0.05$, $\eta^2 = 0.01$ age*location*NTP: $F(15, 1433) = 1.68$, $p < 0.05$, $\eta^2 = 0.02$
Q2: Have capacity	Main effect for years using e-TB Manager $F(1, 1454) = 45.57$, $p < 0.00$, $\eta^2 = 0.03$	Main effect for years working in NTP $F(3, 1433) = 4.29$, $p < 0.01$, $\eta^2 = 0.01$
Q3: Do not need more training	Main effect for location: $F(2, 1454) = 6.22$, $p < 0.01$, $\eta^2 = 0.01$ Main effect for years using e-TB Manager: $F(1, 1454) = 20.99$, $p < 0.00$, $\eta^2 = 0.01$ location*e-TB Manager: $F(2, 1454) = 5.95$, $p < 0.01$, $\eta^2 = 0.01$	Main effect for location: $F(2, 1433) = 8.15$, $p < 0.00$, $\eta^2 = 0.01$
Q4: Support and infrastructure	Main effect for location $F(2, 1454) = 5.93$, $p < 0.01$, $\eta^2 = 0.01$	Main effect for location: $F(2, 1433) = 3.95$, $p < 0.05$, $\eta^2 = 0.01$
Q5: enter or find information	Main effect for location: $F(2, 1454) = 5.35$, $p < 0.01$, $\eta^2 = 0.01$ Main effect for years using e-TB Manager: $F(1, 1454) = 7.85$, $p < 0.01$, $\eta^2 = 0.01$ location*e-TB Manager: $F(2, 1454) = 4.46$, $p < 0.05$, $\eta^2 = 0.01$	Main effect for location $F(2, 1433) = 5.12$, $p < 0.01$, $\eta^2 = 0.01$
Q6: Case management	Main effect for years using e-TB Manager: $F(1, 1454) = 12.75$, $p < 0.00$, $\eta^2 = 0.01$ age*location: $F(6, 1454) = 2.17$, $p < 0.05$, $\eta^2 = 0.01$ location*e-TB Manager: $F(2, 1454) = 4.52$, $p < 0.05$, $\eta^2 = 0.01$	Main effect for years working in NTP: $F(3, 1433) = 3.11$, $p < 0.05$, $\eta^2 = 0.01$
Q7: Training is adequate	Main effect for location: $F(2, 1454) = 3.89$, $p < 0.05$, $\eta^2 = 0.01$ Main effect for years using e-TB Manager: $F(1, 1454) = 30.55$, $p < 0.00$, $\eta^2 = 0.02$	Main effect for years working in NTP: $F(3, 1433) = 5.90$, $p < 0.01$, $\eta^2 = 0.01$
Q8: Information is available	Main effect for location: $F(2, 1454) = 5.90$, $p < 0.01$, $\eta^2 = 0.01$ Main effect for years using e-TB Manager: $F(1, 1454) = 10.64$, $p < 0.01$, $\eta^2 = 0.01$	Main effect for location: $F(2, 1433) = 7.90$, $p < 0.00$, $\eta^2 = 0.01$ age*NTP: $F(9, 1433) = 2.87$, $p < 0.01$, $\eta^2 = 0.02$ age*location*NTP: $F(15, 1433) = 1.67$, $p < 0.05$, $\eta^2 = 0.02$
Q9: Paper system is faster [a]	age*location*e-TB Manager: $F(6, 1454) = 5.10$, $p < 0.00$, $\eta^2 = 0.02$	age*location*NTP: $F(15, 1433) = 1.69$, $p < 0.05$, $\eta^2 = 0.02$
Q10: Errors or inaccuracies [a]	Main effect for location: $F(2, 1454) = 4.42$, $p < 0.05$, $\eta^2 = 0.01$ age*location: $F(6, 1454) = 2.10$, $p < 0.05$, $\eta^2 = 0.01$	Main effect for location: $F(2, 1433) = 3.02$, $p < 0.05$, $\eta^2 = 0.00$
Q11: Workplace productivity	Main effect for years using e-TB Manager $F(1, 1454) = 8.79$, $p < 0.01$, $\eta^2 = 0.01$	age*NTP $F(9, 1433) = 2.87$, $p < 0.01$, $\eta^2 = 0.02$
Q12: Reliable	Main effect for location: $F(2, 1454) = 3.85$, $p < 0.05$, $\eta^2 = 0.01$ Main effect for years using e-TB Manager: $F(1, 1454) = 7.48$, $p < 0.01$, $\eta^2 = 0.00$ Age*location: $F(6, 1454) = 2.36$, $p < 0.05$, $\eta^2 = 0.01$	Main effect for location $F(2, 1433) = 5.23$, $p < 0.01$, $\eta^2 = 0.01$

[a] Reverse worded questions.

age*location*years working with NTP for satisfaction (Q1), information is available for case management (Q8) and that paper system is faster than e-TB Manager (Q9) (Table 7). No other three-way interaction was significant. Older respondents aged over 50, regardless of location and with at least 6 or more years of experience in NTP, had higher mean satisfaction scores than did their younger counterparts. There was a significant two-way interaction for age*years working in a TB program for both patient information being avail-

able in e-TB Manager and improved workplace productivity due to e-TB Manager. Regardless of location and among users with more than 11 years of experience, users aged 40–49 had higher mean scores (M = 5.67, SD = 1.67) than users aged over 50 (M = 4.84, SD = 1.93) for workplace productivity.

3.4. Comparison of aggregate country responses

Appendix C provides the mean scores for the 12 core questions in each country with corresponding results from Scheffe's post-hoc tests. This section only provides an overview of the results, and p values are shown in Appendix C. Bangladesh had significantly higher mean scores for satisfaction with e-TB Manager than did Armenia, Nigeria, and Indonesia. For the question, "I have the required capacity to use all features of e-TB Manager linked to my responsibilities", only Ukraine had a significantly higher mean score than Indonesia. However, for "the training I received on e-TB Manager is adequate," Ukraine, Brazil, and Vietnam had significantly higher mean scores than Bangladesh, Cambodia, and Indonesia. Nigeria had a significantly higher mean score than Bangladesh for adequacy of training received.

Bangladesh had a significantly higher mean score than Nigeria or Armenia concerning the length of time needed to enter or find information in e-TB Manager. Compared to Brazil, Armenia, Nigeria, and Indonesia, Ukraine had significantly higher mean scores for the belief that e-TB Manager helps improve patient case management and for the statement, "The information needed for case management is available in e-TB Manager." Indonesia had a significantly lower mean score than Brazil, Vietnam, Bangladesh, or Cambodia in the level of agreement for e-TB Manager's help in improving patient case management. Bangladesh and Ukraine had significantly higher mean scores for perceived workplace productivity compared to Brazil, Nigeria, and Indonesia. For perceived reliability of e-TB Manager, Armenia had a significantly lower score than all countries except Indonesia, which also had a significantly lower mean score compared to five other countries. Generally, respondents who disagreed with the specific statements on satisfaction, adequacy of training received, and perceived reliability of e-TB Manager provided justifications for their responses (Appendix D, table D1).

4. Discussion

This was the first large-scale, cross-sectional, anonymous user experience survey of a wide range of e-TB Manager users from nine diverse resource-constrained countries that bear nearly one-third of the world's TB burden [9]. The 86.3% completion rate among responses received for all required questions exceeds the recommended 80% completion rate even in a possible situation of a low average response rate of 25% in survey research [20,21]. However, our survey had a high average response rate of 73.3% among completed responses, which substantially exceeds that of comparable digital health-related surveys in both high-income and developing countries [22,23]. Our survey, therefore, indicates very high engagement of e-TB Manager users from the national decision making level to the health facility level and the validity of our results to all users of the system. While our findings from the e-TB Manager user experience survey may not be generalizable, they offer implications for other eHealth systems in resource-constrained countries.

Implementing eHealth systems in resource-constrained settings is often beset with challenges, including limited infrastructure, poor internet connectivity, and interrupted maintenance of technology [3]. Although our surveyed countries are experiencing these challenges at various levels, the relatively high mean scores from our survey regardless of user characteristics, affirm overall user satisfaction, perceived reliability, and that e-TB Manager helps improve patient case management. With real-time access to patient information, physicians can share their knowledge, for example, from possible special cases they have treated with specific regimens. This information is accessible to other assigned users and permits them to learn from other colleagues' experience and thereby contribute to improved treatment outcomes. Contrary to popular belief and experience in other settings in which older users are likely to resist eHealth systems, our survey of e-TB Manager users found no significant differences for older users [24,25]. The mean scores for satisfaction, having capacity, and e-TB Manager's help in case management increased progressively from younger to older users. This finding is noteworthy particularly among older users aged over 50 and with at least 6 or more years of experience working in the NTP. Regardless of age, having 11 or more years of experience in a NTP, using e-TB Manager for more than two years, and working at the district level than the province level led to significantly higher satisfaction levels and perceived reliability of e-TB Manager.

District-based users tend to utilize e-TB Manager more through entering patient data, updating various data fields, tracking patient adherence, and entering laboratory results, among other tasks. In most high TB-burden countries, there has been steady decentralization of programmatic management of MDR-TB since 2012, which means that it is the responsibility of district-level users to routinely update e-TB Manager with patient adherence data, treatment outcomes, and medicine supply information. Therefore, it is not surprising to find significant differences in mean scores for district-level users' satisfaction and reliability compared to province-level users. Consequently, district-level users differ significantly from province- and central-level staff in their belief that the patient information needed for case management is available. Routine data entry is often the responsibility of district staff, while province- and/or central-level staff aggregate information for surveillance and report generation purposes. If there is missing information in certain fields in e-TB Manager, central and provincial officials reach out to district staff and fill in the gaps because they expect better data quality and completeness; this is similar to experience in other resource-constrained settings [26]. This could also explain why central level staff relies on e-TB Manager to detect errors or inaccuracies in patient files based on their significantly different mean score compared to district level staff.

There were no significant differences in mean scores for age group or location for the perceived capacity of using all e-TB Manager features linked to user responsibilities. However, when asked about the need for additional training and adequacy of training received, users aged 18–29 had significantly lower scores than did users in other age categories. Donors in all surveyed countries financially supported the initial core training for NTPs and national referral hospitals, with the expectation that the NTP would budget for cascade training whether from the Global Fund or from domestic resources. However, frequent turnover of trained public-sector staff common in resource-constrained countries likely hampered this effort either due to low public-sector salaries or job dissatisfaction among other reasons [27,28]. Public-sector health workers and particularly those new to eHealth systems such as e-TB Manager expect to be trained and are disappointed if they do not receiving formal training, but they nevertheless adapt and learn on the job [29,30]. Overall, regardless of age, working in an NTP for less than three years and using e-TB Manager for less than two years are indicators that these users are likely less knowledgeable about the complexities of MDR-TB diagnosis and treatment and the corresponding recording and reporting features in both e-TB Manager and a country's paper-based reporting systems. This finding aligns with other studies measuring health worker knowl-

edge of MDR-TB diagnosis and treatment [31,32]. When an NTP changes or updates MDR-TB clinical guidelines and disseminates them, mass training is usually not given, and clinicians and users alike are expected to keep abreast of new developments and adapt to new changes in TB recording and reporting systems. Even if existing users have received training but MDR-TB guidelines have changed with corresponding updates in e-TB Manager reporting fields, there is typically a user expectation for additional training. From the NTP perspective, limited budgets and competing priorities make refresher training difficult in terms of both cost and time for personnel involved.

Providing routine technical support and infrastructure, such as computers and uninterrupted internet connectivity, is the responsibility of the national-level team and, depending on the country's health system, the government's provincial office. One or more dedicated staff member, usually from the MDR-TB team, oversees data quality and completeness issues, and he or she is available to field calls or emails from users if there are any issues or challenges with e-TB Manager. In some countries, even if computers are provided in a health facility as a precondition for e-TB Manager use, internet connectivity may be unreliable, or there may be two to three users who are expected to share the only available computer. For the question on available support and infrastructure, the mean score was generally low compared to other questions (mean = 4.84, SD = 1.88). However, there were significant differences between older (aged over 50) and younger (aged 18–29) workers, and between those with more than 11 years and less than five years of NTP experience. We note that older public-sector users and those with more than 11 years of experience in NTP (regardless of age) tend to be more tolerant of infrastructure challenges and limited technical support than are younger or less experienced users.

When comparing countries, regardless of user characteristics, we expected Brazil and Ukraine to have relatively high scores for most questions. With more than five years of e-TB Manager use in both countries, institutional capacity has been built. Their NTPs have the ability to adapt to changes and absorb new updates in e-TB Manager, even with turnover of staff and key leaders who have championed e-TB Manager in both countries. Moreover, our project had long-term country presence, a greater number of local staff for technical assistance, and dedicated programming support to respond rapidly to customization requests and adaptations. This could help explain why these two countries generally had higher scores for key measures than other countries where local programmers learned to code e-TB Manager on the job for periodic updates and to fix IT problems. Only Ukraine has a government-authorized law that mandates the use of e-TB Manager as the country's national TB registry [33]. Therefore, users in Ukraine are expected to routinely update e-TB Manager, and the central-level supervision team conducts periodic data quality checks [34]. This explains why Ukraine has the highest score among all countries for information being available in e-TB Manager to help improve case management and having the capacity to use e-TB Manager. Brazil, however, recently had challenges in data quality and infrequent updates in their version of e-TB Manager, as demonstrated by comparatively lower ratings for the same measures. Besides the survey, many users in Brazil provided comments in the open text box related to poor data quality, particularly in e-TB Manager's medicines management module.

Beyond the pilot phase, Indonesia has more years of institutional experience with the nationwide implementation of e-TB Manager than does Bangladesh, which began expansion in 2012. However, Indonesia scored lower than all other countries, while Bangladesh had the highest score for perceived satisfaction and reliability for e-TB Manager. We believe that Indonesia's experience with other eHealth systems suggest that users expected significantly more from e-TB Manager also evidenced by the volume of user comments received (Appendix D, table D2). By contrast, users in Bangladesh's NTP were comparatively new to an eHealth system such as e-TB Manager and therefore had a generally more positive opinion. In addition, Indonesia has two parallel electronic systems in its TB programs and one general health information system, and data are not exchanged among the systems. This could explain user frustration from dealing with one eHealth system for first-line TB diagnoses and treatment and with e-TB Manager for MDR-TB diagnoses and treatment. The new version of e-TB Manager has interoperability features that could address this challenge [35]. However, despite the highest user satisfaction in Bangladesh, these users still expect refreshers and frequent training programs on e-TB Manager, as indicated by lower scores relative to other countries.

The TB burden is higher in Bangladesh and Ukraine than in other countries, and both rated e-TB Manager highly in terms of improving their workplace productivity compared to other countries where users have a lower data-entry burden. With better workplace productivity due to e-TB Manager, nurses can investigate TB patient's contacts, follow-up with patients who are not adhering to treatment, spend more time with patients, and focus on other tasks. By contrast, Namibia, which has a relatively low TB burden, had the highest mean scores among all countries, but the differences were not significant for perceived reliability and workplace productivity. Frequently slow technology and brief system crashes that require data re-entry can undermine user confidence. That could explain Armenia's low scores for the perceived reliability of e-TB Manager and for satisfaction compared to other countries. While the brief episode of system slowness and subsequent data re-entry was fixed in Armenia at least one year prior to the survey, users tend to remember the problem, despite it being a server issue and not a problem with e-TB Manager itself.

5. Strengths and limitations of the study

To our knowledge, this is the first cross-country user experience study in resource-constrained countries of a successfully adopted and institutionalized eHealth system, and it sheds light on many of the factors presented in this paper rather than simply evaluating a pilot project. Evaluations of Open MRS, an eHealth system that is widely used in resource-constrained countries, have been published [13,36,37]. However, our contribution to the existing knowledge base is that our study had a very high response rate for a multi-country, public-sector survey; was conducted in the local language in seven of nine countries; analyzes key user characteristics of an institutionalized eHealth system; and presents the comparable country context of our findings. We strove to implement best practices outlined in survey research as reflected in our methods, and we have provided additional data in Appendix B [19,38]. The translated questionnaire can easily be replicated at a low cost to compare the initial benchmarks established in this study. For example, research in one high-income country evaluated eHealth usability by repeating a previous survey to draw rich comparisons over time [39]. Even before preparation and publication of this paper, a country level report with key survey findings and user comments were promptly channeled back to each country authority for decision making, thereby meeting some of the principles for digital development [40]. For example, based on user comments in the survey, authorities in Ukraine took action to conduct refresher training and addressed specific reporting and infrastructure issues. In Nigeria, the survey findings strengthened the interim decision of authorities to expand use of e-TB Manager to more districts and took into account the resources needed to make it happen. In Brazil, the survey findings and user comments prompted authorities to upgrade the medicines management feature of e-TB

Manager. Our study findings contribute to the growing knowledge base of the eHealth user experience in resource-constrained countries and have implications for other eHealth systems.

There are some limitations to our study. Due to the anonymous nature of the survey, we were unable to compare differences among non-respondents with those who responded to the survey to address non-response bias. We also did not compare early responders with late responders to assess whether there was any influence in the results within a country. For example, we received at least 50% more responses from Bangladesh and Brazil after trying different methods to increase the response rate because users in these countries often lack a valid or updated email address. Long periods of holiday due to Carnival and Easter in Brazil also hampered the initial response rate. In Ukraine, we only had permission to conduct the survey over an eight-week period, which resulted in a country-level response rate of 52%, despite Ukraine having significantly better email outreach and a larger user base compared to other countries. Therefore, comparing early versus late responders within a country is unlikely to have significantly changed our findings. Despite our best efforts to make the survey as clear as possible either in local language for seven countries or in English for two countries, it is likely that some users may have misunderstood the question. The two reverse worded questions (Q9, Q 10) and one negatively worded question (Q 3) may have caught users off guard and affected their response.

Summary points
What was already known on the topic?

- Multi-drug resistant tuberculosis (TB) is a public health crisis.
- Strong electronic recording and reporting systems are fundamental to advance the WHO End TB strategy and meet the Sustainable Development Goal 3 related to health
- After multi-year and nationwide implementation of e-TB Manager, a web-based eHealth system in 10 resource-constrained countries, no user experience evaluation has been performed

What this study added to our knowledge?

- Older respondents aged over 50 generally had higher user experience scores compared to younger counterparts
- More than two years of experience with e-TB Manager resulted in higher user satisfaction, perceived reliability, workplace productivity, and capacity to use e-TB Manager to help in patient care
- Depending on the country context and disease burden, future interventions must take into account unmet learning expectations of younger users by age and inexperienced users in a TB program, regardless of age
- Beyond the pilot phase, after a five-year period with gradual scale-up, institutional capacity was built in Brazil and Ukraine compared to other countries.

6. Conclusions

The WHO's digital health for End TB strategy cited e-TB Manager as an example in contributing to quality patient-centered care and TB program management [7]. Our findings demonstrated that across diverse country health systems with varying TB burdens, users are satisfied with e-TB Manager, find it to be reliable, have the capacity to use e-TB Manager linked to their responsibilities and confirm that it helps improve patient care and improved workplace productivity. Implementing an eHealth system such as e-TB Manager, particularly in large and complex, resource-constrained, high TB-burden settings, requires multi-stakeholder partnerships and organizational agility. There must be committed financial, infrastructural, technical and trained human resources to ensure its sustained use to help improve patient care. After the gradual withdrawal of donor funding, country authorities need to allocate resources for both refresher training and establish e-learning methodologies to keep pace with periodic programmatic changes and improve overall user experience. A digital health technology such as e-TB Manager has the potential to contribute to countries' aspiration to meet the Sustainable Development Goal 3 and end the TB epidemic by 2030.

Authors' contributions

NK conceived of, designed and led the implementation and analysis of the multi-country study. All authors participated in the survey adaptation and finalization. NK, LGVB, and LFAR contributed to country-specific implementation methods and strategy. KS analyzed various survey platforms and performed the statistical analysis. NK, KS, LGVB performed the primary interpretation of the study findings. LFAR validated primary study findings. NK wrote and finalized the manuscript. LGVB provided critical intellectual input for the analysis and interpretation of the study findings. All authors reviewed and approved the manuscript.

Statement on conflicts of interest

None declared.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ijmedinf.2017.03.017.

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