Evaluating The Performance Of Malaysian Health Care Providers With Partial Least Squares Path Modeling

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Abstract

Background: The Ministry of Health Malaysia invested significant resources to implement an electronic health record (EHR) system to ensure the full automation of hospitals for coordinated care delivery. Thus, evaluating whether the system has been utilized effectively is necessary, particularly on how it predicts the work performance of the health care providers.

Methods: Convenience sampling was employed for data collection in three government hospitals for seven months. A standardized effectiveness survey for EHR systems was administered to health care providers (specialists, medical officers, and nurses) as they participated in medical education programs. Power analysis was conducted before and after the study to ensure adequate sample sizes and sufficient power. The empirical data was assessed by employing partial least squares-structural equation modeling for hypotheses testing.

Results: As a result, knowledge quality had the highest score in predicting performance and had a large effect size, whereas system compatibility became the strongest component of system quality. The findings indicated that EHR systems supported the clinical tasks and workflows of care providers, which increased system quality, whereas increased quality of knowledge improved user performance.

Conclusion: Therefore, knowledge quality and effective use should be incorporated into the evaluation study of EHR system effectiveness in health institutions. Data mining feature can be integrated into current systems for generating health populations and disease trend analysis easily and systematically, therefore improving clinical knowledge of care providers and effective use to maintain their productivity. The validated survey instrument can be further tested with empirical surveys in other public and private hospitals with different interoperable EHR systems.

Background

Electronic Health Records (EHRs) System

Electronic health records (EHRs) are created from integrated health information systems via secured computer networks. These networks are available to authorized care providers to be used for consultation and exchange purposes across health care settings [1]. In Malaysia, the EHR or hospital information system (HIS) is used to create EHRs in order to ensure full automation of hospitals and coordinated care delivery among various providers [2]. However, due to policy restrictions, the hospitals in Malaysia have been implementing a non-sharable EHR system which is operated by a single or multiple authorized care providers within a particular facility [3]. In this system, the medical records of patients cannot be taken or used outside the hospital area.

In this work, the term HIS is adopted in reviewing the current literature, and the term EHR system is used in discussing the research model, the methodology adopted, the results of the study, and discussion of the
findings. The term *EHR system* is chosen because it appropriately represents the use of clinical IS by health care providers to perform clinical tasks.

### The Adoption of EHR System in Malaysia

The benefits of EHR systems are largely recognized to support greater care, reduce medical resources, and improve clinical decisions [4]. However, without a systematic evaluation, the use of the system could negatively affect the job performance of clinical staff. In Malaysian tertiary referral centers, the use of clinical care IS was found to contradict the workflows of doctors, their task complexities, and their work environments [5]. The doctors appeared to resist using the systems due to inconvenient interface and functions, which have created much data entry mistakes hence medication errors [6].

In one study, a group of researchers ([7] identified the critical success factors in HIS by systematically reviewing pertinent studies published over the past twenty years (1996–2015). The review uncovered that human factor was the most critical dimension in achieving the success of HIS adoption. Another study concludes that the successful application of HIS depends on how well the technology is implemented and how its use can improve the performance of health care providers and hospitals [8]. In another research, Mohamadali and Zahari [9] recognized the challenges in the implementation of HIS in the Malaysian health industry to be (a) workflow disruptions with changing and complicated processes, (b) long training procedures for learning HIS handling, (c) poor computer hardware and network connectivity, and (d) loss of interest of physicians and nurses in using HIS due to lack of IT skills. All these factors were found to contribute to decreased adoption levels and productivity. Therefore, the “fit” among systems, records, technical support service, and knowledge is crucial in supporting the widespread acceptance of EHR systems and productivity of health care personnel [8, 10, 11].

The problems stated above give rise to the following question: To what extent do the quality of EHR systems, records, support service, and knowledge positively influence the effective use and performance of the Malaysian health care providers? Existing studies in the local context have nevertheless focused on the adoption and acceptance of the EHR system and vaguely evaluated the performance of the providers in using the systems [8–10, 12]. This gap necessitated the development of a practical model that allows Malaysian clinicians to effectively use the EHR systems to potentially improve their work performance. Accordingly, the present study aims to evaluate the effects of several quality predictors based on the effective use of EHR systems on the performance of health care providers.

The study would be significant to the decision makers at the ministry level and hospitals that are currently using the EHR systems because the findings will reveal whether adopting the system can render a positive effect on clinicians’ performance, as predicted by several proposed measures. Accordingly, the proposed survey questionnaire will be tested and validated to be a diagnostic tool for future HIS evaluation. The assessment will enable hospitals to measure the performance of their care providers in using the systems in a mandatory setting.

### Methods
Theoretical Gaps

Quantitative researchers have commonly adopted the DeLone and McLean (D&M) models to evaluate the effectiveness of IS [13, 14]. This evaluation framework has been generally applied to assess how several success factors can positively affect individuals and organizations. However, the D&M models appear to be common and therefore, additional assessments are required to identify other potential factors that can positively influence the performance of clinicians in using the EHR systems.

An EHR system can manage and disseminate information to share knowledge and advance clinical research across multiple interoperable systems. Hence, a quality evaluation of IS should integrate knowledge quality for completion [15]. The use of the D&M model is also irrelevant due to the mandatory use of the EHR system [16, 17], and therefore, the model must be revised with improved measure for IS user performance when the usage is compulsory [2].

In measuring the success of IS, the D&M models delineate user satisfaction. However, a high relationship exists among system quality, information quality, and individual effect of user satisfaction construct [18], thus the low explanatory capability due to recurring measures [19]. Based on these justifications, user satisfaction is excluded in performance measurement of care providers, but actual use will be improved with effective use.

Research Model and Construct Definitions

Sets of relationships among exogenous, mediating, and endogenous constructs of the proposed research model are illustrated in Figure 1. Each path possesses a positive hypothesized effect. The model comprises three exogenous constructs adopted from the D&M models, namely, system quality, record quality improvement through information quality replacement, service quality [13, 14], and knowledge quality (new construct), which are used as quality predictors. The D&M models are more appropriate for the problems being studied, the technical characteristics, the functionalities of local EHR systems, and the prediction of the final performance outcome of end users (health care providers) than other IT acceptance and user models, such as unified theory of acceptance and use of technology, technology acceptance model 2, and technology acceptance model 3. To measure every relationship among the constructs in this model, a quantitative study design that uses distributed surveys was applied to the target samples. The collected empirical data are subjected to partial least squares (PLS) analysis [20] to determine the most critical predictors for the performance of care providers.

In a clinical setting, “system quality” refers to adequate IT infrastructure, system interoperability, perceived security concern, and compatibility of EHR systems with clinical tasks performed by care providers [21].
Records quality depends on timely access, consistency, standardization, accuracy, duplication prevention, and the completeness of EHRs generated from the system. Record term is preferred to information output because the former accurately describes the definition of EHRs as the repository of patient data available in digital format, which is stored, shared, secured, and accessed by authorized providers to support continuous and quality care [3, 22]. Examples of EHRs are patient treatment notes, images, laboratory test results, prescriptions, discharge summaries, patient histories, and medical reports [22]. Service quality denotes the quality of technical support delivered by EHR system vendors and internal IT personnel used to measure effective use and clinicians’ performance.

As a newly proposed construct, knowledge quality refers to the extent to which the health care providers can learn, create new knowledge, and apply what they have learned from an EHR system [15]. All these can be done by consulting EHRs, clinician workflows, and best clinical practices, which can be applied in making right decisions and solving the problems of patients. A prior study by Chang et al. [15] found that knowledge quality had insignificant effect on user satisfaction in using knowledge management systems (KMSs). In particular, the study disclosed that only few Taiwan medical centres have EMR repository, provide data analysis services to their clinicians, and manage EMRs to acquire hospital accreditation, but not totally to support primary care. On the contrary, knowledge quality was found to be the main factor that contributed to user satisfaction and the benefits of KMS, as perceived by the top-50 Taiwanese firms, thus proving that the use of KMSs supported the dissemination of useful knowledge and enabled the firms to gain competitive advantage [23].

An enhanced effective use is identified as a mediator that enables clinicians to accomplish their clinical tasks without committing significant medical errors and misdiagnosis, and prescribing inaccurate medications. Accordingly, the performance of the health care providers relies on the quality of the system, the EHRs, the technical support service, their clinical knowledge, and the effective use as the final endogenous or outcome construct.

**Study Hypotheses**

**System Quality**

In the execution of clinical operations, the use of EHR relies on IT facilities, which in turn, influence the quality of patient care [24]. Doctors’ professional practices can be enhanced with excellent network connectivity [25].
In essence, interoperability means the capability of an EHR system to access, use, transmit, and exchange EHRs from multiple integrated systems [26]. The interoperability of systems will enable a timely access to patient records for the benefits of cost reduction, speedy treatment, prevention of duplicated tests, and gradual improvement of doctor-and-patient relationships [21, 27].

In a clinical setting, system security is the capability of HIS to protect the users and records from unauthorized access and against virus and bug threats [28]. Audit trails should be continuously improved to ensure that an EHR system grants access to authorized person in the right location and at the right time. In addition, these records should be acquired, stored, preserved, and used correctly and safely for high-standard care delivery [29].

Compatibility of technology to the work environment and organizational culture of health care providers is critical during system adoption [30]. The user will recognize the relative advantage of a system, that is, whether it suits his/her job or style. In addition to task and workflow compatibility, a system design must also comply with standardized clinical practice guidelines (CPGs). CPGs are medical practice statements for a particular disease and are systematically developed from clinical studies and most reliable evidence [31]. CPGs document every detail of clinicians’ decisions in regard to patients’ conditions and recommendations for diagnostic tests or interventions [32]. Evidence has shown a positive influence of EHR on job effect among the physicians in California hospitals [16]. Hence, the hypotheses are as follows:

\[ H_1^a: \text{System quality has a positive effect on the effective use of EHR systems.} \]

\[ H_1^b: \text{System quality has a positive effect on the performance of health care providers.} \]

**Records Quality**

EHR is a summarized version of patients’ health information compiled from their medical records [33]. The implementation of critical-care IS reduces documentation time and increases EHR quality and access time [34], thereby positively affecting the acceptance of the system by doctors and nurses [5]. Similarly, the use of EHR was found to positively affect the clinical tasks of physicians in intensive-care unit. The positive effects included increased time spent on clinical review and documentation [35]. Thus, the hypotheses are as follows:

\[ H_2^a: \text{Records quality has a positive effect on the effective use of EHR systems.} \]

\[ H_2^b: \text{Records quality has a positive effect on the performance of health care providers.} \]
Service Quality

Clinicians often assess the IT products supplied and the quality of support service to ensure that they satisfy the specifications and requirements in health care practices. The positive attitude, performance, and satisfaction of clinical staff thus will improve when service providers deliver a high-quality support service [36]. Notably, the frequency of visits by technical assistance will positively improve the use of an EHR system and the quality of physicians’ works [37]. Hence, the hypotheses are as follows:

\( H3_a: \) Service quality has a positive effect on the effective use of EHR systems.

\( H3_b: \) Service quality has a positive effect on the performance of health care providers.

Knowledge Quality

EHRs primarily aim to integrate knowledge from patients’ health information in averting medical errors, thereby simplifying the analysis, presentation, and use of knowledge from EHRs. Clinical knowledge is generated from tacit knowledge (experiences or professional practices of care provider) which is then converted into the explicit or documented form of CPGs, clinical workflows, and EHRs [15, 23]. An EHR system generates EHRs and stores CPGs and clinical workflows that contain knowledge [38], increasing its quality through sound clinical decisions and improved task productivity of clinicians [10, 33]. Hence, the hypotheses are as follows:

\( H4_a: \) Knowledge quality has a positive effect on the effective use of EHR systems.

\( H4_b: \) Knowledge quality has a positive effect on the performance of health care providers.

Effective Use

The use of an integrated EHR system must enable physicians to complete their clinical tasks without making significant errors. Furthermore, the effective or extended use will positively affect the performance outcomes of physicians and medical practice [39, 40]. The actual use of an EHR system that was previously measured on frequency or duration and extent of use has to be refined with effective use to achieve high individual and organization performance levels [41]. The use of an effective system increases the needs, productivity, satisfaction, and motivation of clinicians to maximize the capabilities of the system [42]. Hence, the hypothesis is as follows:

\( H5: \) The effective use of EHR systems has a positive effect on the performance of health care providers.
METHODS

Survey Questionnaire

An EHR system–user evaluation survey was designed by selecting appropriate questions from past quantitative instruments that were designed based on the D&M models related to the constructs of the proposed study and the local context of EHR system adoption. Responses were submitted through a 7-point Likert scale in which 1 represents “strongly disagree” and 7 denotes “strongly agree.” This scale offers the respondents considerable freedom of selection, as suggested by Redd et al. [43, 44], and should thus be used in a survey instrument for improved reliability and validity after analysis. Prior to the data collection, the questionnaire draft was further reviewed by IT officers from targeted hospitals because they have considerable experience in conducting HIS satisfaction surveys. These officers then recommended that the number of questions be limited to fewer than 50 items to prevent poor response [33]. Three new items were designed to improve the construct of effective use, and five adopted items were proposed as the new constructs of knowledge quality to fit the features and functions of the local EHR system [15, 23]. These additional constructs were also chosen because they were not too technical for the target sample, particularly the nurses, to understand. Two items that have yet to be tested were introduced. In total, 37 items were finalized to be rated on a Likert scale for the field survey.

Sampling Technique and Sample of Population

Convenience sampling was employed in collecting the data because the hectic schedules of the specialists and medical officers in the busy hospital environment limited the use of random sampling. The samples consisted of health care providers (specialists, medical officers, nurses) who were directly engaged in patient care and the active users of EHR systems [10, 33].

Sample Size Estimation and Data Collection

By applying Faul et al.’s [45] guideline, a priori analysis was executed in G*Power 3.1 to compute the required sample size for the field study. The recommended samples were \( N = 146 \) \((f^2 = 0.15 \text{ [medium effect]}, \ a = 0.05, \text{ latent constructs} = 6)\) to ensure the power of 0.95 at 5% level of statistical significance. Hence, a total sample of 438 was required to gather data from the three hospitals.

Upon receiving approval from the Medical Research and Ethics Committee (MREC), the survey questionnaire was administered (a) to the target samples during the continuing medical education (CME)
programs for specialists, medical officers, and assistant medical officers, and (b) to the continuing nursing education (CNE) programs for nurses organized in different government hospitals that were implementing multiple EHR system packages with similar clinical functionalities. In the field survey, sample data were gathered from the three respective hospitals (a) with more than 500 patient beds and (b) which were implementing fully integrated or total EHR systems. Data were collected within a seven-month period. A total of 1200 survey questionnaires were distributed, and Alpha Hospital exhibited the highest usable responses (40%), followed by Gamma Hospital (36%), and Beta Hospital (24%). A final of 888 usable responses were subjected to descriptive analysis in the IBM Statistical Package for the Social Sciences (SPSS).

Sample Characteristics

Table 1 depicts the profile of the sample of respondents. The sample shows unequal representation of male (29%) and female (71%) care providers due to larger percentage of female nurses, specialists, and medical officers in the surveyed hospitals. Majority of them aged between 25 and 35 years (64%) and were nurses and junior medical officers (housemen). More than half of the respondents were nurses (44%) and assistant medical officers (11%) who had a diploma qualification (53%), whereas the medical officers (37%) consist of those with a bachelor and specialist degrees (8%), a master degree (7%), and a doctorate degree (1%). Many of them (53%) have less than 5 years of practice with less than 3 years of experience in using an EHR system.

A common method bias (CMB) was assessed to identify whether the measuring latent constructs explained more than 50% of the variance [46]. Using Harman's one-factor test, the results exhibited that the total variance explained was 32.6%, thus verifying that CMB did not exist in the collected data.

Results

Data Analysis

IS researchers have been applying partial least squares-structural equation modeling (PLS-SEM) due to small sample size, non-normal distributed data, and formative indicators that are inaccurately modeled in covariance based-structural equation modeling (CB-SEM) [47]. PLS path modeling evaluation permits researchers to identify the most potential factors or determinants in predicting target constructs with the aim to extend the present theories. This measure was performed along with the formative measures of system quality that contains different components of technological characteristics [20, 48], and therefore, is considered as the appropriate statistical method for confirmatory factor analysis (CFA) using SmartPLS 3.2.4.

Evaluation of Formative Measurement Model
In the hypothesized model, system quality is measured by adequate IT infrastructure, system interoperability, perceived security concerns, and system compatibility. These formative components represented by indicators that do not highly correlate with each other [20, 48]. For instance, IT infrastructure (required computer hardware, software, and EHR system) is different from an interoperable system (connectivity and workability of different integrated systems), and perceived security concerns are also different from compatibility of system to the clinical tasks performed by care providers. In this study, the formative model was first assessed using a collinearity test. The results however showed that the score of variance inflation factor (VIF) for every formative indicator or item did not reach the critical level of 5, thus confirming that collinearity was not a major issue [47].

The assessment continued with the significance and contributions of formative indicators using the bootstrapping feature (with 5000 subsamples) [20, 48]. The results exhibit that all the system quality indicators are significant at a level of 1%, thereby concluding the validity of system quality components and formative measurement model.

**Evaluation of Reflective Measurement Model**

The analysis proceeded with a reflective model assessment. As presented in Table 2, the factor loadings for most reflective indicators are higher than a standard of 0.7, except for three indicators which are still acceptable [20]. Unfortunately, knowqual_4 indicator with a poor loading of 0.542 is removed to improve composite reliability (CR) and average variance extracted (AVE) for its measuring construct. Also, the CR and AVE for each latent construct exceeds the suggested thresholds of 0.7 for CR and 0.5 for AVE [20], thus establishing a convergent validity for the reflective measures.
| Latent Construct                      | Indicator/Item | Loadings | CR   | AVE  |
|--------------------------------------|----------------|----------|------|------|
| Records Quality                      | recqual_1      | 0.725    | 0.873 | 0.535 |
|                                      | recqual_2      | 0.657    |       |      |
|                                      | recqual_3      | 0.780    |       |      |
|                                      | recqual_4      | 0.783    |       |      |
|                                      | recqual_5      | 0.739    |       |      |
|                                      | recqual_6      | 0.697    |       |      |
| Service Quality                      | servqual_1     | 0.834    | 0.901 | 0.694 |
|                                      | servqual_2     | 0.852    |       |      |
|                                      | servqual_3     | 0.834    |       |      |
|                                      | servqual_4     | 0.811    |       |      |
| Knowledge Quality                    | knowqual_1     | 0.826    | 0.919 | 0.654 |
|                                      | knowqual_2     | 0.817    |       |      |
|                                      | knowqual_3     | 0.858    |       |      |
|                                      | knowqual_5     | 0.746    |       |      |
|                                      | knowqual_6     | 0.803    |       |      |
|                                      | knowqual_7     | 0.799    |       |      |
| Effective Use                        | effuse_1       | 0.677    | 0.846 | 0.649 |
|                                      | effuse_2       | 0.873    |       |      |
|                                      | effuse_3       | 0.853    |       |      |
| Health Care Provider Performance     | hcpert_1       | 0.818    | 0.907 | 0.709 |
|                                      | hcpert_2       | 0.819    |       |      |
|                                      | hcpert_3       | 0.891    |       |      |
|                                      | hcpert_4       | 0.838    |       |      |

Discriminant validity for the reflective measures was subsequently assessed by the mean of the Heterotrait-Monotrait Ratio of Correlations (HTMT) criterion [20]. This new standard provides the most conservative threshold of 0.85 for the reflective measures and the bootstrap confidence intervals must not reach 1 (HTMT < 1) for the statistical inference [20]. As tabulated in Table 3, no value of correlations
above 0.85 was recorded and no upper bound of the confidence interval (CI) for every latent construct was recorded as above 1, thereby concluding that a discriminant validity for the reflective measurement model had been established. In conclusion, the survey questionnaire of EHR system user performance was well validated through the CFA in PLS-SEM.

Table 3  
Heterotrait-monotrait ratio of discriminant validity.

| Latent Construct                  | Effective Use | Health Care Provider Performance | Knowledge Quality | Records Quality |
|----------------------------------|---------------|----------------------------------|-------------------|-----------------|
| Health Care Provider Performance | 0.570         | CI [0.642]                        |                   |                 |
| Knowledge Quality                | 0.473         | 0.838                            | 0.659             |                 |
|                                  | CI [0.551]    | CI [0.882]                        |                   |                 |
| Records Quality                  | 0.554         | 0.715                            | 0.659             |                 |
|                                  | CI [0.631]    | CI [0.769]                        |                   | CI [0.715]      |
| Service Quality                  | 0.354         | 0.590                            | 0.549             | 0.447           |
|                                  | CI [0.446]    | CI [0.662]                        | CI [0.621]        | CI [0.526]      |

Note: CI = Confidence Interval

Path Model Evaluation

Evaluation of the PLS path model began with the coefficients of determination ($R^2$) for the predictive accuracy assessment. The estimated $R^2$ score was 0.641 thus accounting for 64% of the variance for the final target construct. Health care provider performance is explained by the four quality constructs and effective use, which is interpreted as marginally substantial with higher predictive power [49] in the areas of IT acceptance and success.

The second step was to assess the significance of the path relationships among the latent constructs to validate the hypotheses. Again, using a complete bootstrapping of 5000 subsamples for the two-tailed tests with no sign changes, the hypothesis tests were executed. Figure 2 illustrates the path coefficients scores, $t$-values, and $R^2$ scores in the path model. Based on the literature review, system quality was operationalized formatively and was measured by four components. Before running the model assessment, thirteen items on system quality components (reflective indicators) were transformed into their four underlying attributes (formative indicators) through a two-stage approach [50]. This two-stage approach transformation is essential if the path model contains both reflective and formative measures to avoid too many relationships, extreme collinearity, and discriminant validity issue [20, 48].

Evaluation of this path model entailed five latent constructs to test nine hypothesized relationships and effects. The results revealed that all paths are statistically significant except for service quality and
effective use effects. In other word, hypothesis $H_{1a}$, $H_{1b}$, $H_{2a}$, $H_{2b}$, $H_{3b}$, $H_{4a}$, $H_{4b}$, and $H_5$ are supported at either 5% or 1% level of significance. System quality becomes the highest predictor for effective use (path coefficient = 0.317, $t$-value = 5.964) while knowledge quality has the largest path coefficient (0.493) and positive effect ($t$-value = 13.059) on the final target construct.

**Effect Size Assessment**

Path model evaluation continued with the effect sizes ($f^2$) for every study construct over its measuring target construct. In particular, knowledge quality has a large effect size on user performance ($f^2 = 0.370$) followed by service quality ($f^2 = 0.040$, small effect), records quality ($f^2 = 0.025$, small effect), effective use ($f^2 = 0.024$, small effect), and system quality ($f^2 = 0.012$, no effect) [51] These results verify the significant contribution of quality of knowledge learnt from EHR systems in predicting the care providers’ effect.

**Power Analysis**

In validating whether the significance and nonsignificance results of the hypotheses had sufficient statistical power, a posthoc analysis was computed with a linear multiple regression test. Given the effect size ($f^2$) of 1.785, total sample sizes of 888, and latent constructs’ correlation scores, the hypothesized results had an observed power of 1.000 which is categorized as large [51] gathered using a non-probability sampling design, thus concluding the greater statistical power to detect significance and significance effects at a 5% level in the field of IS evaluation research.

**Discussion**

To clarify the results, informal interviews were conducted with six head of clinics (specialists) in the three surveyed hospitals. Following the method recommended by Vaghefi et al. [52], these heads were randomly selected based on their experience in using an EHR system. Discussion of the findings thus begins with an overview of the results, followed by supports from real practices acquired from the interviews and prior literature.

The study determined that system quality is the most important construct in influencing the effective use of an EHR system. An EHR system can perform patient care and record of diagnosis results simultaneously if it is compatible with the workflows of the CPGs and clinicians [27]. If treatment notes are available in a user-friendly template, they enable an easy data entry process and therefore allow more time for the doctors and nurses to communicate with their patients. A user-oriented CIS design enables an efficient use through automatic data checking and filtering, along with timely access [42]. Also, a system interface design that shows full medical histories of patients can support meaningful use [53].

System quality was also found to positively affect user performance. The results indicated that the structure and content of the systems were compatible with the working styles of the care providers. The flow of the systems was designed to fit the different methods of care delivery by clinicians after much
change requests have been updated. As a result, the use of the system will reduce care providers’ workloads from minimal data entry and documentation works, which in turn, increases task productivity. Correspondingly, a cross-sectional survey found that ease of use and HIS efficiency positively affected the job satisfaction and work performance of care providers in southern Taiwan hospitals [28]. Similarly, an online survey with 219 California residents indicated that system quality, information quality, and service quality measures had positive effects on the work impact of physicians [16].

Records quality was also found to positively influence effective use. A standardized, user-friendly format of EHR enables speedy and fewer data entry for the care providers to perform timely diagnosis and treatment without delays. The standardized EHR also (a) improves the consistency of medical records creation among clinics and (b) supports the referral process across other hospitals. By using the auto-complete feature, the doctors can provide the right prescriptions to the pharmacist without making spelling errors. The adoption of critical care system was also found to positively influence doctors and nurses’ acceptance by improving the quality of records and system access besides decreasing data entry [5, 34]. Successful clinical system adoption relies on ease of access, completeness, correctness, and standardized EHRs [42]. As such, high-quality EHRs will significantly improve the efficiency of care and medication by nurses [40, 54].

Records quality was also found to have positive effect on the performance of end users. EHRs store complete patient medical histories extracted from their treatment notes, images, laboratory results, prescriptions, referral activities, and discharge summaries to facilitate a coordinated care among clinics and hospitals from the patients’ birth to death. Instant access to patient EHRs is therefore critical for their responsible care providers to immediately understand the past care, allergies, medications, and follow-ups of patients. In fact, doctors generally do not know about the health status of a patient during his or her first visit. A full and timely access of EHR in hand will avoid further delays, and the providers can deliver the best treatment or transfer care, if necessary, without misdiagnosis, repeated tests or wasted resources, and inaccurate medications, thereby increasing their performance. The current finding thus is in line with the prior studies on EHR adoption. These studies found that the use of EHR had positive effect on the tasks of the physicians in an intensive care unit by allowing more time to be spent on clinical review with multiple physicians simultaneously and less time on performing documentation and administrative works [35]. As indicated in a previous study, the use of EHR also enhances nursing communication skills when interacting and recording patients’ medical records [55].

The relationship between service quality and effective use was found to be positive but nonsignificant, thus signifying user dissatisfaction with the quality of IT technical support. This finding might be due to the frustration of several care providers with the delays in vendor support service following problems with the system or computer. The most frequent technical issues were reportedly related to the low performance of hardware caused by obsolete computers and servers, which complicated the support for an increasing number of system users. System performance was noted to be typically slow during the peak hours in the afternoon when the hospitals receive many patient visits. A few unplanned system downtimes were reported to be triggered by damaged network switches, which forced the users to use
paper-based records. As indicated in a previous study, an insignificant impact is typically triggered by poor technical service quality, such as incompetent staffs, inadequate computers, and much-unplanned frequent network breakdown, and power interruption [56]. Continuous IT support service for EHR systems, computers, and networks as well as effective end-user training indeed are the core determinants to accelerate EHR system adoption [21]. Another previous empirical study also indicated that higher user satisfaction is positively associated with the quality of support service [56].

In contrast, service quality was found to positively influence the performance of health care providers. This effect may be attributed to the efficient follow-up activities by the system vendors, who ensured that user-reported problems were fully resolved. If the problem was related to the operating system, then the help desk support would troubleshoot the problem via a remote desktop. In the case of hardware malfunction, the help desk support will send their staff to the actual location to fix the issue. A follow-up call is made after a few hours to verify that the problems are completely solved, such that the users can perform their jobs with greater satisfaction. Hence, immediate support and approachable staff are concluded to significantly influence greater service quality, which in turn, improves clinicians’ productivity through timely patient care [28].

Knowledge quality was found to positively affect the effective use and have the strongest positive effect on performance among the estimated relationships. The doctors who made the right clinical decisions after reviewing the EHRs would perform timely and best care, hence improving effective use. In addition, housemen can learn past patient care of similar conditions provided by specialists with longer practice. These specialists may improve their medical practices through shared treatment with senior doctors. Experienced clinicians can write a more detailed radiology report compared to their less-experienced juniors. Different specialists with different specialties will record every clinical procedure into the EHRs to be shared and enhanced by other responsible doctors. Not only are the systems used to consult patient records, results, and reports, but they are also capable of creating and disseminating new medical knowledge for efficient problem solving and decision-making by various care providers. The quality of care will increase to the highest standard and positively affect the care providers’ productivity by fully exploring this knowledge. Past research has proven that knowledge quality is positively affected by knowledge management system benefits, system usage, and user satisfaction [23]. Therefore, individual and organizational learning in a health institution must be developed by fostering knowledge creation, storage, and sharing via the use of an EHR system among medical personnel [15].

Effective use of an EHR system was found to positively influence the performance of the care providers. The respondents agreed that they could accomplish their clinical tasks successfully in simple steps. The benefits of the usage have empowered the care providers to perform timely and accurate care without committing any misdiagnosis or prescribing wrong medications [57]. As noted, the benefits include ease of search and retrieval of past medical records of patients, well-structured and customized EHRs, fewer documentation errors, and convenience of use within the hospital facility. This result is consistent with those found in previous empirical studies. Efficient use of an EMR system that is influenced by system functionality, user exploration, and ease of use was found to contribute to greater performance of
physicians [58]. In other studies, effective use of HIS was found to save time for task completion, cut clinical expenses, and enhance care givers’ productivity with minimal medical error [59, 60]. As a result, a boost performance is anticipated by greater satisfaction and task productivity, which eventually lead to increased patient loyalty and hospital reputation [61].

Conclusions And Implications

This study provides two significant contributions to the present theories and methodology. First, the study has produced a validated questionnaire survey on the performance measurement of a user of an EHR system. Second, the study has extended the conventional D&M models by incorporating a new knowledge quality predictor and an enhanced effective system use, which was found to contribute to the greater task performance of multiple health care providers in a mandatory setting. The use of PLS is recommended for predicting the performance of different clinicians when using multiple EHR systems, particularly in terms of quality of systems, records, technical support service, knowledge, and effective use with regard to high statistical power acquired from larger samples.

The study supplies theoretical implications by confirming the quality of new knowledge. Improved effective use constructs were established as the significant predictors and determinants for enhancing the performance of multiple groups of clinicians in three government hospitals with different systems. These two constructs can be considered by future health informatics researchers to evaluate the success of any EHR system during and after implementation.

Practical implications of the findings are also established. The survey instrument can serve as a diagnostic tool that can be readily used by IT hospitals with multiple-system packages to assess the level of EHR system-user performance of specialists, medical officers, and nurses during adoption, particularly when resistance or negative effects on clinical tasks are reported post utilization. Additionally, EHR system vendors can refer to the validated instrument to investigate the causes of certain problems when assessing the implementation of a new system, such as poor implementation and low adoption rate. For increased effectiveness, the system should be further customized to allow the head of clinical departments or system moderator to upload and adjust clinician workloads in compliance with new published CPGs. To increase the productivity of clinicians, knowledge quality and effective use requirements should be integrated into an EHR system design and future upgrades. All the three systems must be upgraded to the latest version of data mining feature so that health care providers can easily learn hospital population, health patterns, and disease trends systematically and efficiently for the early prevention of adverse patient conditions and complications, thereby improving their productivity.

Increased productivity of health personnel can enhance public loyalty toward the government health care system, thus contributing to the effectiveness of EHR systems. The effectiveness of HIS that has received substantial investments can enhance patient care and safety. Policy-makers at the ministry level should design pay-for-performance programs, such as monetary incentives and certificates of appreciation for EHR champions, and research grants to support additional medical researchers. The Ministry of Health Malaysia might consider integrating system quality, records quality, service quality, knowledge quality,
and effective use for future strategic planning associated with the implementation of an upgraded or a
new EHR system.

The study is not without limitations. Nonprobability sampling, which was employed for data collection,
can restrict the generalizability of the findings across other IT hospitals with different complexity of
interoperate EHR systems, packages, and modules. Moreover, the sample recruitment was focused on
CME and CNE programs attended by voluntary health care providers. Only a few specialists participated
in these programs due to their hectic schedules Additionally, the respondents consisted mainly of nurses
and graduate medical officers with less than five years of practice.

In the future study, the use of larger samples from other clinical personnel is recommended. Researchers
might evaluate the effect of system use on the specialty of various care providers when evaluating their
performance by different EHR system modules and packages. Knowledge quality can be further explored
with learning, researching, application of knowledge, decision-making and problem-solving capabilities,
and complete medical source attributes whereas effective use with ease of task completion, accurate
diagnosis, and medication attributes. Then, a comprehensive evaluation is highly recommended to
assess individual and organizational performances in achieving greater user productivity, patient
satisfaction, and quality of health service delivery.

ABBREVIATIONS

AVE Average Variance Extracted
CFA Confirmatory Factor Analysis
CMB Common Method Bias
CME Continuing Medical Education
CNE Continuing Nursing Education
CPG Clinical Practice Guideline
CR Composite Reliability
EHR Electronic Health Record
EMR Electronic Medical Record
HIS Hospital/Health Information System
HTMT Heterotrait-Monotrait Ratio of Correlations
KMS Knowledge Management System
Declarations

Ethics approval and consent to participate

The study was approved by the Medical Research and Ethics Committee, Ministry of Health Malaysia with the reference number NMRR-14-1203-23156 (IIR). All respondents provided their written consent before participating in the survey. Privacy and confidentiality of the respondents maintained throughout the study.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no conflict of interest.

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Authors’ contributions

MIMS and NZ contributed to the conceptualisation, study design, and data collection. MIMS drafted the initial manuscript. RA contributed to data analysis and critically revised the manuscript. All authors, MIMS, RA, and NZ contributed to study design and interpretation; writing, reviewed, revised, and approved the final manuscript.
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Abbreviations

| Abbreviation | Description |
|--------------|-------------|
| AVE          | Average Variance Extracted |
| CFA          | Confirmatory Factor Analysis |
| CMB          | Common Method Bias |
| CME          | Continuing Medical Education |
| CNE          | Continuing Nursing Education |
| CPG          | Clinical Practice Guideline |
| CR           | Composite Reliability |
| EHR          | Electronic Health Record |
| EMR          | Electronic Medical Record |
| HIS          | Hospital/Health Information System |
| HTMT         | Heterotrait-Monotrait Ratio of Correlations |
| KMS          | Knowledge Management System |
| MREC         | Medical Research and Ethics Committee |
### Tables

**Table 1. Characteristics of samples.**

|                      | Frequency (n) | Percentage (%) |
|----------------------|---------------|----------------|
| **Hospital**         |               |                |
| Alpha (iSOFT System) | 353           | 40             |
| Beta (F1S1C1EN® System) | 213       | 24             |
| Gamma (Cerner System) | 322         | 36             |
| **Gender**           |               |                |
| Male                 | 256           | 29             |
| Female               | 632           | 71             |
| **Age Group**        |               |                |
| < 25                 | 121           | 14             |
| 25-35                | 565           | 64             |
| 36-45                | 145           | 16             |
| 46-55                | 47            | 5              |
| > 55                 | 10            | 1              |
| **Education Level**  |               |                |
| Diploma              | 467           | 53             |
| Bachelor Degree      | 350           | 39             |
| Master’s Degree      | 65            | 7              |
| Doctoral Degree/PhD  | 6             | 1              |
| **Clinical Position**|               |                |
| Assistant Medical Officer | 96     | 11             |
| Medical Officer      | 328           | 37             |
| Specialist           | 71            | 8              |
| Nurse                | 393           | 44             |
| **Year of Practice** |               |                |
| < 5                  | 468           | 53             |
| 5-10                 | 231           | 26             |
| 11-20                | 142           | 16             |
| 21-30                | 38            | 4              |
| > 30                 | 9             | 1              |
| **Year of EHR System Use Experience** | | |
| < 3                  | 472           | 53             |
| 3-5                  | 200           | 23             |
| 6-8                  | 120           | 14             |
| 9-11                 | 78            | 9              |
| > 11                 | 18            | 2              |

**Table 2. Convergent validity in reflective model.**
| Latent Construct          | Indicator/Item | Loadings | CR  | AVE  |
|--------------------------|----------------|----------|-----|------|
| Records Quality          | recqual_1      | 0.725    | 0.873 | 0.535 |
|                          | recqual_2      | 0.657    |       |      |
|                          | recqual_3      | 0.780    |       |      |
|                          | recqual_4      | 0.783    |       |      |
|                          | recqual_5      | 0.739    |       |      |
|                          | recqual_6      | 0.697    |       |      |
| Service Quality          | servqual_1     | 0.834    | 0.901 | 0.694 |
|                          | servqual_2     | 0.852    |       |      |
|                          | servqual_3     | 0.834    |       |      |
|                          | servqual_4     | 0.811    |       |      |
| Knowledge Quality        | knowqual_1     | 0.826    | 0.919 | 0.654 |
|                          | knowqual_2     | 0.817    |       |      |
|                          | knowqual_3     | 0.858    |       |      |
|                          | knowqual_5     | 0.746    |       |      |
|                          | knowqual_6     | 0.803    |       |      |
|                          | knowqual_7     | 0.799    |       |      |
| Effective Use            | effuse_1       | 0.677    | 0.846 | 0.649 |
|                          | effuse_2       | 0.873    |       |      |
|                          | effuse_3       | 0.853    |       |      |
| Health Care Provider Performance | hcpert_1 | 0.818    | 0.907 | 0.709 |
|                          | hcpert_2       | 0.819    |       |      |
|                          | hcpert_3       | 0.891    |       |      |
|                          | hcpert_4       | 0.838    |       |      |

Table 3. Heterotrait-monotrait ratio of discriminant validity.

| Latent Construct          | Effective Use | Health Care Provider Performance | Knowledge Quality | Records Quality |
|---------------------------|---------------|----------------------------------|-------------------|-----------------|
| Health Care Provider Performance | 0.570         |                                  |                   |                 |
|                           | CI [0.642]    |                                  |                   |                 |
| Knowledge Quality         | 0.473         | 0.838                            |                   |                 |
|                           | CI [0.551]    |                                  | CI [0.882]        |                 |
| Records Quality           | 0.554         | 0.715                            | 0.659             |                 |
|                           | CI [0.631]    |                                  | CI [0.769]        | CI [0.715]      |
| Service Quality           | 0.354         | 0.590                            | 0.549             | 0.447           |
|                           | CI [0.446]    |                                  | CI [0.662]        | CI [0.621]      | CI [0.526]      |

Note: CI = Confidence Interval

Figures
Sets of relationships among exogenous, mediating, and endogenous constructs of the proposed research model are illustrated in Figure 1.
Figure 2

Figure 2 illustrates the path coefficients scores, t-values, and R² scores in the path model.

Note: ***p < 0.01, **p < 0.05, *p < 0.10.