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Implementation of an Open-Source Electronic Health Record for Decision-Support Education in Medical Informatics

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Abstract. Access to electronic medical record systems is limited in many medical informatics education programs. The objective of this study was to inventory open-source patient record systems with decision support capabilities, implement a system for educational use, and test the effect of the system on students' learning. We sought systems that were under active development, with source code available, having an SQL-queryable database, and having decision support capabilities. We identified 20 candidate electronic health record systems, of which 6 mentioned decision support capabilities in their documentation. Of these, the OpenMRS system appeared to meet all of the requirements for use in our course; however, decision support capabilities needed to be added by use of a custom module implementing Arden2Bytecode, an Arden Syntax interpreter. Students who used this system showed an improvement in their knowledge of decision support systems and their capabilities. We conclude that there are a number of promising open-source electronic patient record systems currently under active development, but decision support capabilities are still immature. We anticipate further developments in this area in the coming years.

Keywords. Free and Open Source Software; electronic health record; decision support systems, clinical; medical informatics education

1. Introduction

Hospitals are moving from using a collection of small systems toward adoption of hospital-wide information systems. One of the major benefits expected from the use of electronic patient records is the ability to re-use data, for uses such as research and improving patient safety through clinical decision support systems (CDSS).

In an environment of many small medical software applications, Medical Informatics Master's students could readily build small tools which solved real information problems and gave them an active learning experience with systems similar to those that they will encounter in their career. Hands-on experience with an electronic patient record has been shown to be beneficial in health informatics education [1]. However, because most systems are closed-source, medical informatics students have no way to see how such systems are designed. This situation is further complicated by non-disclosure clauses, inhibiting the sharing of screen layouts and

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interactions. Future medical informaticians will be expected to build decision support that is integrated with electronic health records; however, currently students can only get hands-on experience with stand-alone systems. With no patient record to use, students can only be educated in terms of knowledge and tested in terms of recall.

As a solution to the above problems, we propose creating a "virtual hospital" using one of the currently-available Free and Open Source electronic patient record systems. "Free and Open Source" (FOSS) means that not only is the software freely available, but the computer code which is used to make the software is also available, and is licensed so that anyone is free to make changes to the software. A number of such systems are available, including some that are in clinical use, particularly in middle-to-low-income countries [2]. However, it is not currently known if any such systems are suitable for use in medical informatics education, and particularly for teaching students about data re-use and building decision support applications.

The objective of this study was to choose a suitable FOSS patient record system with decision support capabilities, implement that system for use in Medical Informatics Master's education, and test the effect of the system on students' learning.

2. Methods

The first step was to select an electronic patient record for use. We searched for systems using an Internet search engine (duckduckgo.com) using synonyms for "open source" and "electronic patient record". This search was conducted on 1 June 2018. This was augmented by searching for lists of systems, using the names found in the first search. This process was repeated iteratively until no new systems were found. We then evaluated the documentation for these systems to assess for suitability for use in our educational program. The requirements were:

- The system should have source code available in a publicly-accessible repository.
- The repository should show current, active development (assessed by the number of contributors and commits in the last year).
- The system should be a hospital system, not a general practice system (systems which accommodate both would be accepted).
- The system should run on the Linux operating system.
- The system should have a database that is queryable in the Standard Query Language (SQL).
- Clinical decision support functionality should allow the creation of simple rule-based reminders.

The search and evaluation was carried out by one researcher (SM) with the results checked by a second researcher (RC).

Systems that appeared to meet the criteria were installed and assessed empirically to confirm that it met our needs. Once a system was selected, it was implemented on virtual machines and populated with synthetic patients. The data were generated to emulate the data quality problems found in actual patient record data: thus, the data set had missing data, data entry errors, misuse of coding systems, etc. Each group of students was made the "administrator" of a patient record system on a virtual machine. The 3-week assignment was to implement the recommendations for anticoagulant management from the ESC 2010 Guidelines for Atrial Fibrillation [3], assess the

accuracy of the advice generated by their system, and make a recommendation as to whether decision support should be implemented for the rest of the guideline.

Achievement of the learning goals was assessed through a voluntary pre- and post-test, which gave scenarios that CDSS implementers might encounter and asked the students to choose a course of action (Analyzing/Evaluating levels of Bloom's taxonomy). Students assigned to a different project served as non-randomized controls for students who completed this assignment. Statistical testing was not performed, due to the small number of students in the course.

3. Results

We identified 20 systems, of which 2 (OpenMRS and Bahmni) were judged to be suitable for use in our educational program. Bahmni is an extension of OpenMRS, thus we chose the core OpenMRS system for further investigation. Of the 20 systems identified in our search, 13 appeared to no longer be actively maintained (last commit > 1 year prior to the assessment). These systems were: FreeMed, OSCAR EMR, and openMAXIMS (last commit in 2017); ClearHealth, TolvenEMR, and UltimateEMR (last commit in 2016); Care2x (last commit 2015); WorldVisa and the Astronaut VistA installer (last commit 2014); OpenVista, LiUEEE (last commit in 2013); and OneTouchEMR and Solismed (no source code found). The other 7 systems, and the results of the assessment, are given in Table 1.

Table 1. Open-source electronic patient record systems identified by our search, and the results of assessment for suitability for decision-support education based on available documentation.

system	sourcecode repository	active development	hospital or GP	SQL variant	CDSS functionality
OpenMRS	github	303 contributors	hospital	MySQL	yes
Bahmni (based on OpenMRS)	github	78 contributors	hospital	MySQL	yes
OSEHRA VistA	github	3 contributors, 300 commits,	hospital	requires M-to-SQL	yes
OpenEMR	github	100 contributors	ambulatory	MySQL	yes
GnuHealth	gnu.org	2 contributors, 179 commits	hospital	PostgreSQL	maybe in an add-on module
OpenClinic GA	sourceforge	1 contributor, 22 commits	hospital	MySQL	unclear
Open Hospital	sourceforge	2 contributors, 80 commits	hospital	MySQL	unclear

All systems were cross-platform and thus met the criteria of being able to run on Linux virtual machines. Most systems were SQL-queryable, although derivatives of the Veteran's Administration's VistA system are written in the M programming language which incorporates a "no-SQL"-like database, and thus are not SQL queryable. Only a few systems had decision support functionality; the VistA-based systems, OpenEMR, OpenMRS, and Bahmni (which is based on OpenMRS). At the time, the decision support capabilities of OpenEMR were very simple, and it was designed for ambulatory rather than inpatient use.

Although the documentation for OpenMRS discussed support for Arden Syntax Medical Logic Modules (MLMs), an HL7-standard domain-specific language for

decision support, empirical evaluation showed no decision support capabilities in the current version. However, OpenMRS had good plugin support and used a standard interface (JDBC) to connect to its database. Therefore we were able to create a new OpenMRS addon module which supported the integration of Arden MLMs (see https://github.com/RSSchermer/openmrs-module-ardenreminders) using Arden2Bytecode, an existing FOSS Arden Syntax interpreter [4]. The system was hosted by a local service provider (Slash24 B.V.).

In the learning goals assessment, all 40 students completed the pre-test and 31 completed the post-test. Students who would later do the CDSS project (CDSS group, n=14) had a median pre-test score of 29% (IQR 15%-43%), while students doing other projects (non-CDSS, n=26) had a median pre-test score of 46% (IQR 34%-57%). On the post-test, the CDSS group showed a median absolute improvement of 10% (n=10, IQR 1-16%) while the non-CDSS group showed a median absolute improvement of 4% (n=21, IQR -4%-12%).

4. Discussion

We successfully incorporated an open-source patient record system with decision support in our Medical Informatics Master's program. The search for candidate systems identified 20 open-source patient record systems, of which 2 were suitable for use in our curriculum. Only 6 of the 20 systems had decision support capabilities; all of these were based on one of three core systems: OpenEMR, the Veteran's Administration VistA system, or OpenMRS. We were able to build a decision support module and implement it in OpenMRS. Assessment of students' mastery of the learning goals suggested that use of the system did aid in understanding the learning goals, although the number of students is too small to draw firm conclusions.

The strengths of our approach include a systematic assessment of the available candidate systems. However, the landscape of open-source systems is changing rapidly; this assessment should be considered a snapshot of the current state of the field. The main limitation is the small number of students in each group. Furthermore, in this year's class, we had 20 foreign exchange students, most with computer science backgrounds, participating in our class. By chance, a majority of the students in the CDSS group were foreign exchange students. This meant that only two regular Master's students completed both the pre- and post-test (with pre-test scores of 42% and 66%, and post-test absolute improvement of 12% and 15%). Although improvement for these two students was similar to that of the foreign exchange students, improvement in the CDSS group may still be attributable to the fact that the majority of these students had more room for improvement. However, it is encouraging that post-test scores on the learning goals assessment were acceptable even for students who started with little to no medical informatics background. We plan to continue to use the system and monitor its effect on learning goals, including the use of other methods for assessing learning goals.

A recent study assessed the capabilities of FOSS electronic health records, including their decision support capabilities [5]. The authors found 12 of the 20 systems that we found, plus an additional 5 systems not identified in this review (all of which appear not to be under current development or do not have source code available). They also found that OpenEMR and VistA were the systems that offered

decision support [5]. An earlier review of FOSS electronic health record systems did not assess decision support capabilities [6].

For our course, we used a custom-built decision support module integrated with OpenMRS. Previous efforts included the integration of an Arden Service, used by the Child Health Improvement through Computer Automation (CHICA) project [7]. Currently, OpenMRS does not have native decision support capabilities, but there are a number of promising efforts to add this functionality. For example, Kabukye et al. are working to develop a care pathway (including decision support) for oncology patients in low-resource settings [8]. Partners in Health is working to implement support for the triage of patients using the South African Triage System [9]. We intend to contribute to the development of other CDSS options, including integration of CDS Hooks and/or HL7 FHIR-based decision support, and we hope that future projects will include contributions from our own students to the OpenMRS code base

On the basis of this work, we conclude that there are a number of FOSS patient record systems under active development. However, the decision support capabilities of these systems are, at this time, limited. We successfully implemented an open-source patient record for teaching purposes: OpenMRS with a custom Arden Syntax module. Use of this system seemed to help students achieve the learning goals of the course. We look forward to future developments in decision support in open-source software.

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