Framework for a web-based breast imaging learning module built on the open-source CAISIS platform and integrated with the new Breast Imaging EMR and existing breast imaging information technology infrastructure at Capital District Health Authority

by

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Acknowledgement and Endorsement

This report has been written by me and has not received any previous academic credit at this or any other institution.

The internship work described in this report to create a framework for a breast imaging learning module is part of a much larger project that has evolved over the last several years under the umbrella of the Breast Health Data Infrastructure Initiative (BHDII). Through this initiative, an interdisciplinary group of radiologists, academic researchers, radiation technologists and breast screening program managers have collaborated to develop BIEMR, a new Breast Imaging EMR. The driving force and guiding vision behind the BIEMR project has been provided by Professor Mohamed Abdolell, who also first proposed the idea to build a breast imaging learning module and integrate it with the BIEMR system. I would like to extend my most heartfelt thanks to Prof. Abdolell for giving me with the opportunity to join a well-established project and work together with the BIEMR group on developing a new breast imaging learning module. In addition, Prof. Abdolell gave substantial input to the project and provided ample guidance, support and feedback throughout the duration of my internship that enabled the production of this final report. I would also like to thank Dr. Judy Caines, Dr. Sian Iles, Theresa Foley, Sarah McCarthy, Dr. Jennifer Payne, Kaitlyn Tsuruda and Ryan Duggan for all their support and their many valuable contributions throughout the duration of this internship. This project would not have been possible without support and resources provided by the departments and organizations listed below.

Department of Diagnostic Radiology, Dalhousie University (DR-Dal)
Department of Diagnostic Imaging (CDHA)
Eastern Health, Newfoundland and Labrador
Nova Scotia Breast Screening Program (NSBSP)
Breast Screening Program of Newfoundland/Labrador (BSPNL)

(signature)

Mete Erdogan

Executive Summary

This report describes the work performed during an 18-week summer internship in the Department of Diagnostic Radiology at Capital District Health Authority (CDHA) by Master of Health Informatics (MHI) candidate Mete Erdogan as part of the requirements for the MHI program at Dalhousie University in Halifax, Nova Scotia). The internship project involved designing and developing a framework for building a web-based breast imaging learning module that is integrated with the existing breast imaging IT infrastructure at CDHA and the new Breast Imaging EMR (BIEMR). BIEMR was built upon the open-source CAISIS data management system and is currently in the final stages of user acceptance testing.

Nova Scotia is the only province in Canada that has an organized breast screening program with full capture of all breast imaging taking place within the province in a single database. The Nova Scotia Breast Screening Program (NSBSP) was created as a provincial program in 1991 by the NS Department of Health & Wellness and given a mandate that includes monitoring the delivery of certain clinical services. Recently, the program completed a three-year process to upgrade the mammographic imaging equipment at every fixed site (screening and diagnostic) across the province from the traditional film-based mammography to Full-Field Digital Mammography (digital mammography or FFDM). The NSBSP is now in the process of updating their information technology (IT) infrastructure to better manage their needs following this transition to FFDM technology. Working together, a group of radiologists, academic researchers, radiation technologists and breast screening program managers from Nova Scotia and Newfoundland have collaborated to develop a the BIEMR system, built upon the open-source CAISIS clinical and research database platform.

The goal of this internship project was to conceptualize a web-based breast imaging learning module that would provide radiologists, radiology residents, and radiation technologists with access to previous imaging cases for self-review and self-teaching purposes. Traditionally, radiology education and depended on teaching file repositories based on paper and film, making them prone to physical deterioration and limiting the ways in which the files could be created, stored, used and shared. Advances in digital imaging technologies such as the picture archive and communication system (PACS) environment and full-field digital mammography (FFDM) have opened the door to a new era of teaching in radiology. The development of a BIEMR Learning

Module (BIEMR-LM) will provide an online educational resource and tool for radiologists, radiology residents, and mammography technologists to improve their ability to accurately read or acquire digital breast images and allow for radiologists and technologists to access and review any previous imaging cases stored in the CAISIS database as part of a work-up review system. The framework presented here proposes a number of open-source software solutions for the development of an online teaching file system for radiology. Going forward, it is recommended that the new BIEMR-LM be developed fully within the CAISIS platform using open-source tools.

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1. Introduction

The Master of Health Informatics (MHI) program at Dalhousie University offers students the opportunity to gain valuable first-hand work experience by performing a summer internship in a healthcare setting. This report details the internship work that was performed by the MHI candidate, Mete Erdogan[1], over an 18-week period between April and September of 2012. The internship took place in the Department of Diagnostic Radiology at Capital District Health Authority (CDHA) under the supervision of Professor Mohamed Abdolell. The goal of the internship project was to generate a framework for building and implementing a web-based breast imaging learning module that is integrated with both the existing breast imaging IT infrastructure and the new Breast Imaging EMR[2] system. The proposed web-based breast imaging learning module (referred to hereafter as BIEMR-LM) will be designed for radiologists, radiology residents, and mammography technologists to use as an educational resource and for work-up review purposes.

This internship report will describe the work performed by the MHI intern during the planning and developmental stages of the BIEMR-LM project. Section 1 of the report will provide the reader with background information on radiology education, open-source software and BIEMR. This section will be used to describe the objectives of the BIEMR-LM project and to outline the contributions made by the author during the internship. Section 2 will provide an overview of breast imaging in Nova Scotia and the organization where the BIEMR-LM is being planned and developed. Section 3 will describe the internship position, the role of the intern on the project team and the responsibilities of the intern. Section 4 will discuss the relevance of the BIEMR-LM project as it relates to the MHI program and the field of health informatics. Section 5 will describe a key challenge faced during the internship and how it was resolved. This section will also describe two possible scenarios for building a teaching management system and show some preliminary screen designs for the BIEMR-LM user interface. Section 6 will summarize key points from the internship and provide concluding remarks. In section 7, the author will give their recommendation of an IT solution for developing and implementing the BIEMR-LM.

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[1] "Author" and "intern" are used interchangeably in this report to refer to Mete Erdogan.

[2] BIEMR is an open-source module built on the CAISIS platform that manages the information (screening and diagnostic imaging) of an organized breast screening program (www.biemr.org).

1.1 Background

1.1.1 Radiology in the Digital Age

Radiology is largely based on the acquisition and interpretation of images (Wong, 1999). Over the course of their professional development, radiologists must acquire and maintain an extensive mental knowledge base of images and be able to evaluate any new cases they see against that accumulated body of information (Cosson & Willis, 2011). The concept of radiologists sharing interesting images among colleagues and with radiology residents is not new (Scarsbrook, Graham & Perriss, 2006). Teaching files have long been an important educational resource for preserving and sharing knowledge in the field of radiology (Lim & Yang, 2006). A particularly effective approach involves the review of selected case materials, including radiographic films and supporting text material that indicates the eventual clinical diagnosis (Pinto, Brunese, Pinto, Acampora, & Romano, 2011). Traditionally, film-based teaching file systems have been used for case-based radiology education, often including the relevant images from the case, the relevant clinical data and a short summary of the pathological condition.

Recent years have witnessed a digital transformation in the practice of radiology (Robson, 2010). The introduction of the picture archiving and communication systems (PACS) environment for radiology and the transition from conventional film mammography to digital mammography, film-based teaching files are quickly becoming obsolete and incompatible with the digital environment of the modern radiology department (Robson, 2010). With digital teaching files, selected images and appropriate information are stored electronically and then recalled for review on a personal computer (Tertuis du Plessis, 2010). The rapid development of the world-wide-web has also significantly changed how information and communications are being handled today (Lim & Yang, 2006). These digital and web-based technologies are increasingly shaping how radiology is being performed and how medical applications for breast imaging are being developed, shifting the emphasis towards web-based implementations.

1.1.2 Open-Source Software

Open-source software (OSS) follows the terms of distribution that are given in the Open-Source Definition (Open-Source Initiative, 2006) and whose license is approved by the Open-Source Initiative (OSI). The essence of OSS is in the licensing terms, which allow for the free use, sharing, and modification of the software. While the copyright owner maintains the moral rights

and some economic rights to the software, many rights are transferred to the software's users and developers. The foundation of the open-source model is built on four essential user freedoms as outlined by the Open-Source Initiative (Open Source Initiative, 2006):

1) Freedom to run the program for any purpose.
2) Freedom to study how the program works and change it as desired.
3) Freedom to redistribute copies of the program.
4) Freedom to distribute copies of your modified versions of the program to others for the benefit of all in the community.

Proprietary licensed software keeps the source code secret, thus keeping the user of the software dependent on the vendor for customizing the code, fixing software bugs, and releasing newer improved versions of the product. The owner of proprietary software can legally exclude any party that it wishes to from using, copying, examining, or sharing the software. OSS licenses in contrast provide basic rights to both the licensee and the user of the software. The most common OSS license is the GNU's Not Unix (GNU) General Public License (GPL), which is used by approximately 65% of OSS (Reynolds, 2011), has been the reference model for many other license agreements over the past 15 years.

1.2 Project Objectives

The overall objective of the BIEMR-LM project is to plan, develop, and implement a web-based breast imaging learning module built upon the CAISIS platform that integrates with existing breast imaging IT infrastructure and the new Breast Imaging EMR. The BIEMR-LM will also be integrated with a new BIEMR Clinical Rounds Module (BIEMR-CRM) that is currently under development.

1.2.1 The BIEMR-LM

The BIEMR-LM will be built on the open-source CAISIS[3] platform. While planning and development for the BIEMR-LM is taking place at CDHA in Halifax, the module will be purposefully designed in a manner such that other departments and institutions apart from breast

[3] CAISIS is an open source, web-based cancer data management system that integrates research and patient care (www.caisis.org).

imaging and CDHA that are interested in adopting an online digital radiology teaching system will be able to download and easily modify the source code of the open-source BIEMR-LM to fit their needs. Upon completion of the BIEMR-LM project, the modified source code will be sent back to the core CAISIS development team in the United States who will evaluate the BIEMR-LM and consider whether the new module would have broad appeal and should be incorporated into upcoming versions of the CAISIS system. Once implemented, the BIEMR-LM will be made available to any group or organization using BIEMR and CAISIS. The final product will be a web-based breast imaging learning module with two main functions.

1.2.2 BIEMR-LM: A Teaching Management System

The first function of the BIEMR-LM will be to provide a platform for a teaching management system (TMS) that captures and displays selected teaching cases for radiologists and radiology residents to use as a training and assessment tool. This system will enable quick and easy creation of teaching files during routine clinical workflow. Breast images of interest that are flagged through the BIEMR-CRM or flagged through other review processes in the BIEMR system (i.e. screening or diagnostic reporting) will also be automatically sent to the TMS. The BIEMR-LM TMS will have a user interface with a template screen that automatically populates with patient data retrieved from the CAISIS database once a command is made to create a new teaching file. For their time spent using this system, radiologists will receive credit towards the Maintenance of Competence (MOCOMP) Program of the Royal College of Physicians and Surgeons of Canada (RCPSC) as part of their continuing medical education (CME).

A critical step in development of the BIEMR-LM will be building the infrastructure for online courses and deciding whether to adopt and integrate a suitable learning management system (LMS). The LMS will provide a platform for capturing and displaying selected teaching cases for radiologists and radiology residents to use as a training and ongoing assessment tool. The LMS would need to include functionality for:

- efficiently identifying, capturing, storing and displaying selected breast imaging cases.
- testing, evaluating, and tracking the ability of radiologists and radiology residents to correctly diagnose selected cases flagged through the BIEMR-CRM or other review processes.

- recording the amount of time individual radiologists spend reviewing cases in order to receive credit towards their MOCOMP as part of their CME.

1.2.3 BIEMR-LM: A Work-up Review System

The second function of the BIEMR-LM will be to provide radiologists and mammography technologists with a work-up review system (WRS) developed within CAISIS that automatically captures and displays specific cases flagged through BIEMR or the BIEMR-CRM. These cases will be available for review by radiologists and mammography technologists, along with access to any other previous work-ups that were performed on a patient. Using this work-up review process, radiologists and mammography technologists will be able to formally document their findings upon reassessment and receive credit towards their CME. For quality assurance purposes a listing of cases that were flagged for poor image quality along with the identity of the imaging technologists will be regularly generated and automatically forwarded to the Quality Control officer at CDHA

1.2.4 Benefits of the BIEMR-LM

The BIEMR-LM will incorporate a feedback learning approach designed for radiologists, radiology residents, and mammography technologists to engage in routine self-teaching, self-assessment, and self-review activities. Case-based learning using selected breast imaging cases will provide valuable experience for radiologists and radiology residents with the interpretation of breast images and the diagnosis of breast cancers. The BIEMR-LM will also function as an online portal for radiologists and mammography technologists to access any breast imaging cases that have been flagged through the BIEMR-CRM or through other review processes (i.e. screening or diagnostic reporting). Cases may be flagged by a radiologist or mammography technologists for a number of issues including poor imaging quality, poor positioning of the patient, movement during image capture, and for non-standard patient positioning during a work up that cannot be reproduced at a later stage for that patient (eg. when having a core biopsy performed). Through this work-up review process radiologists will be able to formally note and submit their findings upon case reassessment and receive MOCOMP credit, and mammography technologists will be able to document their review of past cases for CME credit. Importantly, the BIEMR-LM will provide a highly efficient electronic mechanism for tracking cases that were

poorly imaged for quality assurance purposes. A listing of cases flagged for poor image quality along with identity of the technologists imaging those cases will be generated regularly and sent automatically to the Quality Control officer at CDHA. The benefits of developing and implementing a highly efficient and user friendly breast imaging learning module specifically customized to meet the needs of radiologists, radiology residents, and mammography technologists include:

- increased opportunities for radiologist and radiology residents to gain experience with breast imaging interpretation and proper breast cancer diagnosis and receive credit towards their CME.
- establishing a work-up review process for radiologists and mammography technologists to reassess any previous work-ups in BIEMR and receive credit towards their CME.
- increased collaboration and the promotion of relationship-building and knowledge-sharing activities among radiologists, mammography technologists and radiology residents.
- improving the efficiency of the quality assurance process by encouraging clinicians and technologists to review their own performance and streamlining the QA workflow by automatically sending a listing of poorly imaged cases to the Quality Control officer.

1.3 Intern Contributions to the BIEMR-LM Project

The intern worked together with a team of radiologists, academics, researchers, and the NSBSP to plan out and develop a framework to guide the implementation of a breast imaging learning module at CDHA. Over the course of the internship, the intern researched key issues surrounding interoperability and the transfer, storage, and retrieval of teaching file data. As part of the framework for the BIEMR-LM, the intern generated a project scope document outlining the key objectives, requirements, deliverables, team members, necessary resources, and a project timeline. The intern worked to conceptualize a number of different scenarios for building a breast imaging learning module using both proprietary and open-source software solutions. In addition the intern worked together with radiologists to develop a customized template screen for the quick and easy creation of teaching files during their routine clinical workflow and reporting.

2. Breast Imaging in Nova Scotia

The province of Nova Scotia has the 2nd highest estimated incidence of breast cancer in Canada and the third highest estimated mortality (Canadian Cancer Statistics, 2011). Currently the most effective screening tool for detecting breast cancer at an early stage is mammography (Wadden & Doyle, 2005) as early detection greatly improves the chances for survival (Benson et al., 2009). Randomized controlled studies have also shown that women who have screening mammography included as part of their care are less likely to die from breast cancer than women who do not participate in organized breast screening programs (Doyle et al., 2011).

2.1 Organized Breast Screening and the NSBSP

In Nova Scotia all screening and diagnostic breast imaging is captured under the umbrella of the NSBSP in a single database. The NSBSP was established in1991 and is a provincial program of the NS Department of Health and Wellness. Currently there are 11 fixed screening sites across the province, along with three mobile mammography units that travel to reach rural and remote populations. One of the main goals of the NSBSP is to standardize the mammography process throughout Nova Scotia. The mandate of the NSBSP includes providing cost-effective breast screening for women in NS aged 50-69, developing guidelines and standards for breast screening at sites across the province, and reviewing the delivery of certain clinical services. The clinical workflow for breast imaging in NS is complicated as there are multiple pathways a patient can take through the system, depending on their age, sex, personal history, familial history, and any high risk factors they might have (Appendix A).

Recently the NS Department of Health made a commitment to roll over all screening sites in NS from film-screen mammography to Full-Field Digital Mammography, a process that started in 2007 and was completed in May 2010 when the last site made the transition to FFDM. Presently all breast imaging information is being acquired, retrieved, stored and transferred electronically across the province. As this transition to digital technology was taking place the NSBSP was in the process of updating their IT infrastructure to better manage the screening and diagnostic imaging requirements of a provincial breast screening program in the age of FFDM. Working together, a group of academics, clinicians, researchers, radiation technologists and the breast

screening programs of Nova Scotia and Newfoundland collaborated to develop an open-source system for breast screening and surveillance.

This group of individuals, now known as the BIEMR group, worked together to develop BIEMR, a Breast Imaging EMR that is built upon the CAISIS clinical and research database platform. The BIEMR group is part of the Breast Health Data Infrastructure Initiative (BHDII). The BIEMR system is currently in the final stages of user acceptance testing and will soon be ready for implementation in both Nova Scotia and Newfoundland & Labrador. Planning is in place for BIEMR implementation in the North West Territories and additional provinces have expressed their interest as well in the BIEMR system. To further leverage *** the significant inter-provincial investment in digital technology, the BIEMR group proposed to develop and implement the BIEMR-LM, a breast imaging learning module for use by radiologists, radiology residents, and mammography technologists to improve their ongoing performance and provide departmental quality assurance.

2.2 Radiology Education

The widespread adoption of digital breast imaging technology in NS has made it possible for breast images to be acquired, stored, viewed, and transferred electronically. Studies have shown that successful early detection of breast cancer depends on the accuracy of mammogram interpretation (Van den Biggelaar, Nelemans, & Flobbe, 2008). Better training and more reading experience is associated with lower recall rates and higher detection rates (Feig, 2004). Studies have shown that a computer database for training radiologists improves their diagnostic accuracy and reduces the number of errors made in reading radiologic images (Gutmark, Halsted, Perry, & Gold, 2007) (Mullins, Will, Mehta, & Novelline, 2001). Studies further suggest that the level of expertise for radiologists in interpreting mammograms is related to the amount of training they have received (LoRusso et al., 2006) and that radiologists who have less training produce higher rates of false positives and false negatives (Halsted et al., 2004).

The goal of this internship project was to create a framework for the development and implementation of a breast imaging learning module built on the CAISIS platform and integrated with existing hospital information systems and the new BIEMR system. The BIEMR-LM will create an online educational resource for radiologists and radiology residents to use for self-teaching and assessment purposes, allowing them to gain valuable training experience through

the process of reviewing and interpreting selected case materials including radiographic films, pathology, histology, and supporting documentation indicating the eventual clinical diagnosis. It will also provide access to a work-up review system built in CAISIS that radiologists and mammography technologists can use to access any flagged or previous cases stored in the BIEMR system.

3. Work Performed During Internship

The job description for the internship project is shown below.

3.1 Internship Job Description

The intern will be required to work with the BIEMR team to implement a teaching module for radiology residents in mammography. The teaching module must establish a simple process for radiologists to create teaching files for residents through the course of their regular clinical practice. This will entail scoping the requirements (working with radiologists, researchers and software developers), sourcing content, designing a framework for evaluating student performance, identifying a course management system that can integrate with the CAISIS platform, conducting UAT (both from the perspective of the student and the radiologist), incorporating feedback, documenting the final product. The intern will need to communicate regularly and clearly with a multidisciplinary team locally and internationally and possess solid project management skills. Additionally, the intern will be required to use a course management system to host the educational content and track student progress. Knowledge of SQL and relational databases is a plus.

3.2 Job Duties

The deliverable for this internship project is a framework for a web-based breast imaging learning module built on the CAISIS platform and integrated with the Breast Imaging EMR and existing IT infrastructure at CDHA. The role of the intern on the project team included outlining the scope for the project, identifying the requirements and the necessary resources, identifying team members and their roles, outlining the deliverables and setting a timeline for the project. The intern was responsible for conceptualizing the infrastructure for hosting the patient data online as a teaching file system and whether to integrate an appropriate learning management system for the project, if such a system exists. This was a critical step in development of the BIEMR-LM. The LMS would need to be modular in design and integrate well with both BIEMR and the CAISIS platform. The LMS must also provide the means to manage, track, and evaluate the performance of radiologists and radiology residents as they go through the teaching files. If such an external learning management system does not integrate well then a custom-built solution in CAISIS will be considered.

The responsibilities of the intern included planning and designing an appropriate interface for the creation of teaching files as part of the clinical workflow within the radiology department. This included determining the layout, structure, navigation, and necessary fields for a template screen that is opened on a breast imaging workstation once a radiologist or mammography technologist has identified an interesting image during their routine reporting and selected it for inclusion in the teaching file system. Importantly, the template form must automatically populate with as much patient data as possible from the BIEMR system and provide an easily accessible and useable method for generating teaching files. Furthermore, the intern was responsible for sourcing the content (breast imaging cases and associated materials) that will be added to the LMS, and for determining a mechanism by which radiologists and mammography technologists receive credit towards their CME for using the BIEMR-LM to review previous cases.

The author worked together with another MHI intern (Maher Shawli, currently developing the BIEMR-CRM) in planning for integration of the BIEMR-LM and BIEMR-CRM so that any case reviewed during clinical rounds can be flagged and sent directly to the BIEMR-LM to create a new teaching file. The intern was also responsible for arranging both internal and external reviews to ensure that the content and information flow within the BIEMR-LM is easy to use and appropriate for the purposes of education and self-review. User acceptance testing of the new system from both the perspective of student and radiologist will also be performed, including identification of potential problems, troubleshooting, and determination of the resources necessary for ongoing support and maintenance of the BIEMR-LM.

4. Relevance of the BIEMR-LM Project to Health Informatics

During the internship period, the author was exposed to a wide range of informatics-based concepts that relate directly to materials and information presented through coursework and workshops during the intern's first year of study in the MHI program at Dalhousie. These concepts included:

- understanding how to model and map out clinical workflow and information flow in healthcare settings.
- understanding how to manage an IT project and how to communicate effectively with members of the project team and to appropriately address (when necessary) and deal with issues that threaten the success of the project.
- understanding how to plan and prepare a scoping document for an IT project.
- understanding how electronic medical record are developed and integrated with existing legacy systems.
- understanding issues regarding standards and interoperability among diverse hospital information systems.
- understanding how to develop and customization a template user interface with structured fields for automatically importing or manually entering patient data.
- understanding the roles of clinical coding and terminology in capturing patient data.
- understanding databases and how they are created, managed, searched, and integrated with other hospital information systems.
- understanding how the internet and computer networks are formed and operate.
- understanding the role of web-based medical tools and applications in healthcare.
- understanding the benefits and limitations of implementing commercial proprietary software versus open-source software in a healthcare environment.

Sections 4.1 to 4.6 describe the MHI courses and workshops that were attended by the author and the concepts that were covered which relate directly to the work performed during the internship project. The courses and workshops listed below were the most beneficial in terms of providing the preparation required for the author to understand the concepts (listed above) that were encountered during the course of the internship. Participation in the MHI program also helped the

author to significantly improve his ability to effectively communicate concepts relating to health and information technology, both orally and in written format.

4.1 Health Informatics Flow and Use

HINF 6101: Health Informatics Flow and Use

Course Instructor: Dr. Katrina Hurley

Concepts covered: Understanding the generation, collection, movement, storage, and use of health information in various healthcare environments. This course was instructive in defining the concept of "health" itself and explaining how the healthcare system functions in Canada. Importantly, this course taught how various types of information flow through the healthcare system, how information is communicated, searched, structured and stored, and the role of information systems such as electronic medical records and how they operate within healthcare settings. Importantly, this course gave the author the opportunity to work on a team project for a "real-world" client, Ms. Merida Merrick, Program Coordinator for the Canadian Hospital's Injury Reporting and Prevention Program (CHIRPP) at the IWK Health Center. Through this group project, the author learned to work effectively as part of a team, to identify problems associated with the flow of information through a healthcare institution and to propose a suitable informatics-based solution.

4.2 Networks and the Web for Health Informatics

HINF 6220: Networks and Web for HI

Course Instructor: Prof. Ashraf Abusharekh

Concepts covered: This course was very helpful to the author for conceptualizing and understanding how the internet works, how information is transmitted across the world wide web and the protocols involved in communicating over the internet. This course introduced the author to databases and how they are built and structured, how information is stored and retrieved from databases on the web, and how computers can be linked together to create integrated information systems. This course was also instructive for teaching the intern the basic principles of programming using MySQL and PHP, and how to design, model, and create a database. The background information that was gained through this course was very valuable in teaching the author the basic nature of computing and computer networks.

4.3 Health Informatics Systems and Issues

HINF 6110: HI Systems & Issues

Course Instructor: Dr. Samina Abidi

Concepts covered: This course provided a good overview of health information systems, how they operate, and their roles within various healthcare settings. Important concepts that were learned include the development and implementation of health information systems and the associated issues that commonly act as barriers to the acceptance and integration of different information systems. The course included detailed description and discussion of various hospital information systems including electronic medical records and their role in the Canadian healthcare system. Furthermore, through the group project the author gained first-hand experience working with a client (Dr. Robert Abraham, Interventional Radiologist at CDHA) to map out the existing information flow through the interventional radiology department and proposing a informatics-based solution that was based on using the open-source CAISIS platform to create a new integrated system that addressed their clinical and research needs.

4.4 Health Informatics Flow and Standards

HINF 6102: HI Flow and Standards

Course Instructor: Dr. Grace Paterson

Concepts covered: This course provided a fundamental understanding of how patient information flows through various systems with an emphasis on issues surrounding interoperability, coding, and standardization. These issues were identified during the internship project in the development of a new hospital information system to be integrated with the legacy systems. This course also taught the intern to develop and work with structured templates for entering patient data. Additionally, the group project in the course taught the intern different methods for modeling the information flow through a healthcare organization and to work effectively as part of a team.

4.5 IT Project Management

HINF 6300: IT Project Management

Course Instructor: Prof. Dwight Fischer

Concepts covered: The concepts and issues learned and discussed in this course were seen throughout the term of the internship project. These included the creation of a scoping document for an IT project, learning the proper steps for planning and implementing an IT project, and understanding the most common barriers to the successful and timely delivery of a project to the client. Importantly, this course highlighted the importance of working effectively with others when managing an IT project. This course also gave the intern the opportunity to work in a group on a "real-world" IT project to propose a governance model and a framework for ensuring the long term sustainability of the open-source Breast Imaging EMR under development at CDHA.

4.6 MHI Workshops

A number of helpful workshops were offered to students as part of the MHI program. In particular, the "Ref Works Workshop" given by Gwendolyn MacNairn was very helpful for the author to learn how to search for literature efficiently and effectively using the library system at Dalhousie. It was also a tremendous pleasure and wonderful experience for the author to attend and participate in the "Tuning Up Your Thinking Skills Workshop" given by the late Dr. Sunny Marche. Dr. Marche's presentation was inspirational and highly engaging, and his unique style, charm, and sense of humor left a lasting impression that will not be forgotton. The author is grateful to Dr. Marche for his many contributions to Dalhousie and for sharing with the intern tools that he developed to enhance and improve the mental processes used for thinking, critical analysis and decision-making.

5. Challenges Facing the BIEMR-LM Project

The goal of this internship project was to conceptualize a web-based breast imaging learning module that would provide radiologists, radiology residents, and radiation technologists with access to previous imaging cases for self-review and self-teaching purposes. Information technology infrastructure is critical to the success of imaging in a population-based breast screening program (Robson, 2010). Recently, the province of Nova Scotia completed a three-year process to upgrade the mammographic imaging equipment at every fixed site (screening and diagnostic) across the province from film-based mammography to digital mammography. The NSBSP is now in the process of updating their information technology (IT) infrastructure to better manage their needs following this transition to FFDM technology. Working together, a group of radiologists, academic researchers, radiation technologists and breast screening program managers from Nova Scotia and Newfoundland have collaborated to develop a the BIEMR system, built upon the open-source CAISIS clinical and research database platform. The current IT infrastructure for breast imaging at CDHA is unable to address the needs of the radiologists for creating teaching files easily and quickly during their routine clinical workflow. While the current PACS in use at CDHA (Agfa IMAX 6.5) does have some functionality for creating teaching files, this system is difficult to use and not integrated with BIEMR. The driving impetus for the development a new system for creating teaching files arose from radiologists at CDHA who were frustrated with the current system as it was not easy to use and failed to meet their needs.

The intern was tasked with designing and developing a framework for building and implementing a breast imaging learning module at CDHA intended for radiologists, radiology residents, and mammography technologists to use for educational and work-up review purposes. One of the main challenges arose when deciding whether to use a proprietary or open-source solution to create the new teaching file system.

5.1 Open-Source Versus Proprietary Software Solutions

The open-source software concept enables innovation by giving users additional flexibility and far more transparency than proprietary software vendors allow (Loiterman 2010). The spirit of the open-source movement is having the source code available to the public and shared freely

(Lerner & Tirole, 2001). Individual users can modify the source code to create new modules or additional software functionalities, and then return the code they've modified back to the core development team to be shared for the benefit of all users of the software. Despite its open nature, open-source software security has been shown to be as good as or better than proprietary software in many cases (Boulanger, 2005).

Open-source solutions have been proven to reduce costs while improving the reliability, availability, and integration of health care information (e-Cology Corporation, 2003). The most immediate cost savings are with hardware expenses and operating system licensing costs. Long-term costs associated with open-source solutions include the cost of implementation, costs incurred with service and support issues, and costs associated with investment in infrastructure as organizational requirements evolve over time (Loiterman, 2010). A common concern about OSS among health professionals is the lack of support when compared to proprietary software (Malik & Paton, 2008). Open-source projects tend to rely upon online community networks to deliver support via forums and blogs. While these online communities provide much support and guidance for users, they cannot always provide the level of responsive service, support, and accountability that proprietary software vendors can offer. At the same time, it should not be assumed that a proprietary product from a large vendor will always be well-supported if something goes wrong, as demonstrated in this recent online post by a practicing radiologist in the United States (Friedman, 2012):

> *"Our Agfa IMPAX 6.5 failed for over three hours this past weekend, and that's not the first time that's happened. This sent the three hospitals it services into complete pandemonium, as you might expect. At the moment, there is no hardware disaster recovery option. I've received no word from Agfa as to why they think this might be happening, nor when it will be fixed. Personally, I would hesitate to buy anything new until I knew the answers to these questions."*

Apart from the concern over technical support for OSS, additional concerns have been voiced about the use of open-source software (Jones et al., 2008). These include the possibility that some features may be available with proprietary software that may not be available with OSS software and vice-versa. There is also no guarantee that development will occur with OSS projects, there may be significant problems associated with intellectual property rights, and sometimes it can be

difficult to know that an OSS project exists and what its current status is. Despite these concerns the open-source movement has continued to gain strength and provides an increasingly attractive option for many healthcare institutions looking for an affordable and customizable solution (Hogarth & Turner, 2005). Fundamentally, the open-source movement is about creating a collaborative environment for problem solving.

5.1.1 Open-Source and Proprietary Learning Management Systems

Learning Management Systems include a broad range of applications that go by a variety of names including Course Management System (CMS), Collaborative Learning Environments (CLE), and Virtual Learning Environments (VLE) (Reigeluth et al., 2008). LMS are available in two broad categories: open-source and proprietary. Open-source solutions are increasingly being preferred over traditional vendor-based solutions for a number of reasons. Today's top open-source LMS provide features that rival and in some cases surpass their proprietary counterparts (Ellaway & Martin, 2008), including:

- control, scalability, flexibility, ease of customization.
- enterprise-grade stability and security.
- tools for communication such as discussion forums.
- reporting analytics on system usage.
- generally lower long-term costs, faster bug fixes, and quicker releases of newer improved versions of the product.

5.1.2 Choosing a Suitable LMS for the BIEMR-LM TMS

Over the course of the internship, the author met regularly with radiologists, researchers and representatives of the NSBSP to determine their requirements for the BIEMR-LM and the functionalities they wanted to see in the final product. Based on these discussions the intern was able to determine the requirements of the client for the BIEMR-LM TMS, which include:

- an e-Learning platform that can handle course registration, content storage and delivery, administration, assessments, and reporting.
- design and integration of a customized template for generating teaching files with data fields that populate automatically with relevant case information from the CAISIS database once a command is given to create a new teaching file.
- ability to monitor site usage including the progress and evaluation of residents.

- ability to have a variety of user types with differing levels of authority and privileges for accessing and managing the learning module.

The intern evaluated a number of commercial and open-source LMS offerings, taking into consideration all the needs and requirements of CDHA and the NSBSP as well as their budget and resource availability. Two of the leading open-source learning management systems currently available are the Ilias LMS and the Moodle CMS. The strengths and weaknesses of two systems are described below in sections 5.1.3 and 5.1.4.

5.1.3 Ilias e-Learning Platform

Since 1997, the Integrated, Information, Cooperation and Working System (ILIAS) has been in continuous development as an object-oriented learning management system. ILIAS is written in PHP code, used worldwide and available in 22 languages (www.ilias.de).

Strengths of the Ilias LMS:

- Modular architecture (does suffer from tight coupling).
- Highly customizable
- Flexible role-based permission system granting different permission to four general types of users: Learners, Authors, Lecturers and Administrators.
- Good interoperability with interfaces that allow integration into existing IT infrastructure
- Very good system scalability. System is robust and stable.
- Look and feel is configurable, supports changes in header and CSS.
- Good security.
- Very open development process.
- Small but active developer community, active and helpful medium-sized user community.

Weaknesses of the Ilias LMS:

- System architecture is complex (tight coupling).
- The code is well structured but the architecture is confusing and lacks documentation.
- Tracing and fixing bugs can prove daunting.
- Limited end-user documentation, some developer documentation.
- Poor accessibility (for users of alternative browsers such as screen readers)

5.1.4 Moodle Course Management System

First released in 2002, Moodle is a student-centered learning management system designed to help educators create online courses. Moodle is written in PHP code and maintains a network of over one million registered users who interact through the Moodle website (www.moodle.org).

Strengths of the Moodle CMS:

- A modular, extensible architecture with low coupling and high cohesion.
- A lively developer community.
- Very flexible and customizable.
- Widely portable

Weaknesses of the Moodle CMS:

- The system for granting roles and permissions is limited.

5.2 Open-Source Solutions for the BIEMR-LM Teaching Management System

Working together with the BIEMR group, the intern conceptualized a number of possible informatics-based solutions for building a teaching management system (TMS) into the BIEMR-LM. Two candidate scenarios for constructing the TMS are described below in sections 5.3.1 and 5.3.2.

5.2.1 Integrating MIRC and Ilias with the BIEMR-LM

This first scenario is outlined and described in Figure 1. This concept is based on an online learning system that was developed at Johannes Gutenberg University (Mainz, Germany) in order to improve the diagnostic skills and abilities of medical students studying radiology (Mildenberger, Bruggemann, Rosner, Koch, & Ahlers, 2011). This system takes advantage of the Medical Image Resource Center (MIRC), which is an open-source solution that has been developed by the Radiological Society of North America (RSNA) as a method for the creation of teaching files for radiology. Ilias is an open-source learning management system that provides infrastructure for online courses and teaching. Teaching file cases on MIRC are accessed through the Ilias open-source LMS. A key part of this system is the TCE Selector Tool, an open-source software that provides a client side DICOM instance receiving selected PACS images from a workstation. This tool provides a user interface that can be used by the radiologist to enter

additional information for the case that will be incorporated into a new teaching file. This file will be automatically de-identified, pseudonymised, and exported over the network to the MIRC site where it will be available for use (Mildenberger et al., 2011).

5.2.2 TMS built fully within CAISIS

The second scenario, shown and described in Figure 2, is a custom built solution where the teaching management system for the BIEMR-LM will be developed fully within the CAISIS platform. This scenario for the BILM-LM TMS involves creating a template user interface within CAISIS (BIEMR Teaching Case Creator) that automatically populates patient data pulled directly from the BIEMR system when a radiologist or radiation technologist chooses to create a new teaching case. This interface would include an area to enter comments or additional information in a free-text field. The infrastructure for an online course management system will be built within CAISIS and will import and display patient images and data (stored on a separate file server) as a structured teaching file once a teaching case has been completed and submitted by an end-user accessing the BIEMR-LM.

5.3 Preliminary BIEMR-LM Screen Design and Layout

During the internship, the author worked together with radiologists and members of the NSBSP to conceptualize the user interface for the BIEMR-LM. Preliminary screen designs for the BIEMR-LM TMS and the BIEMR-LM WRS are shown in sections 5.3.1 and 5.3.2. A sample screen to access the BIEMR-LM from CAISIS is shown in Figure 3.

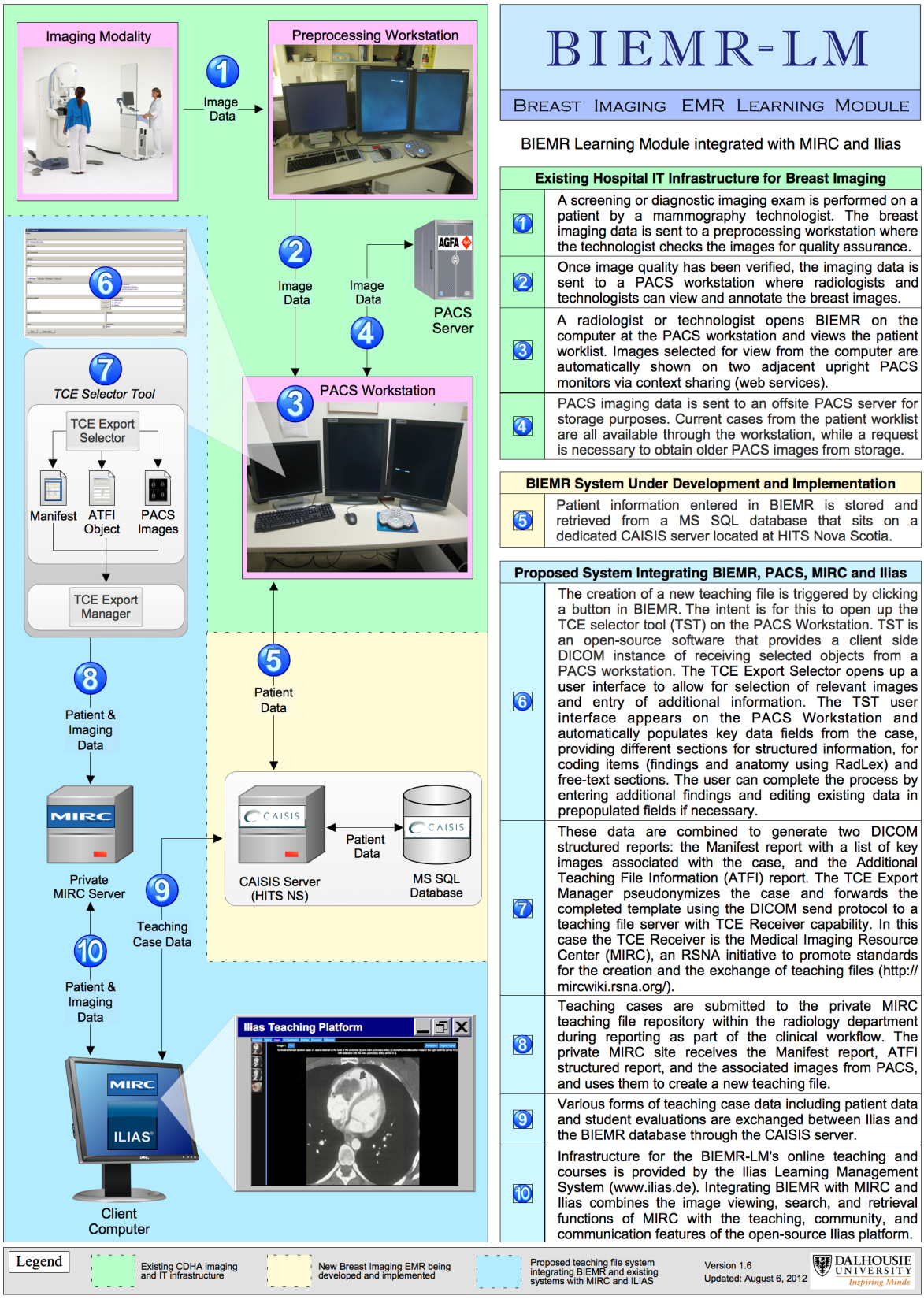

Figure 1: Creating a TMS using MIRC and Ilias

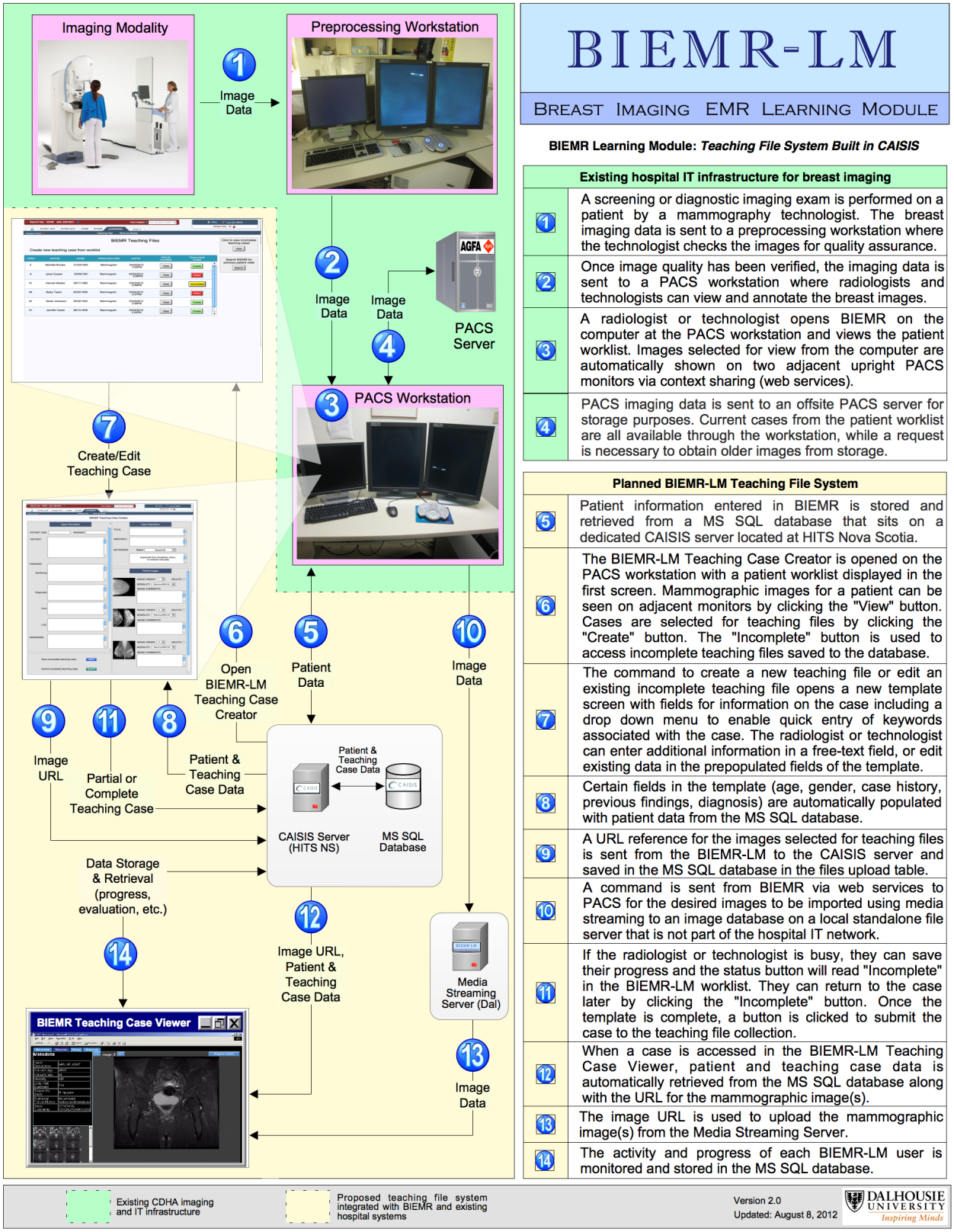

Figure 2: Building a TMS within CAISIS

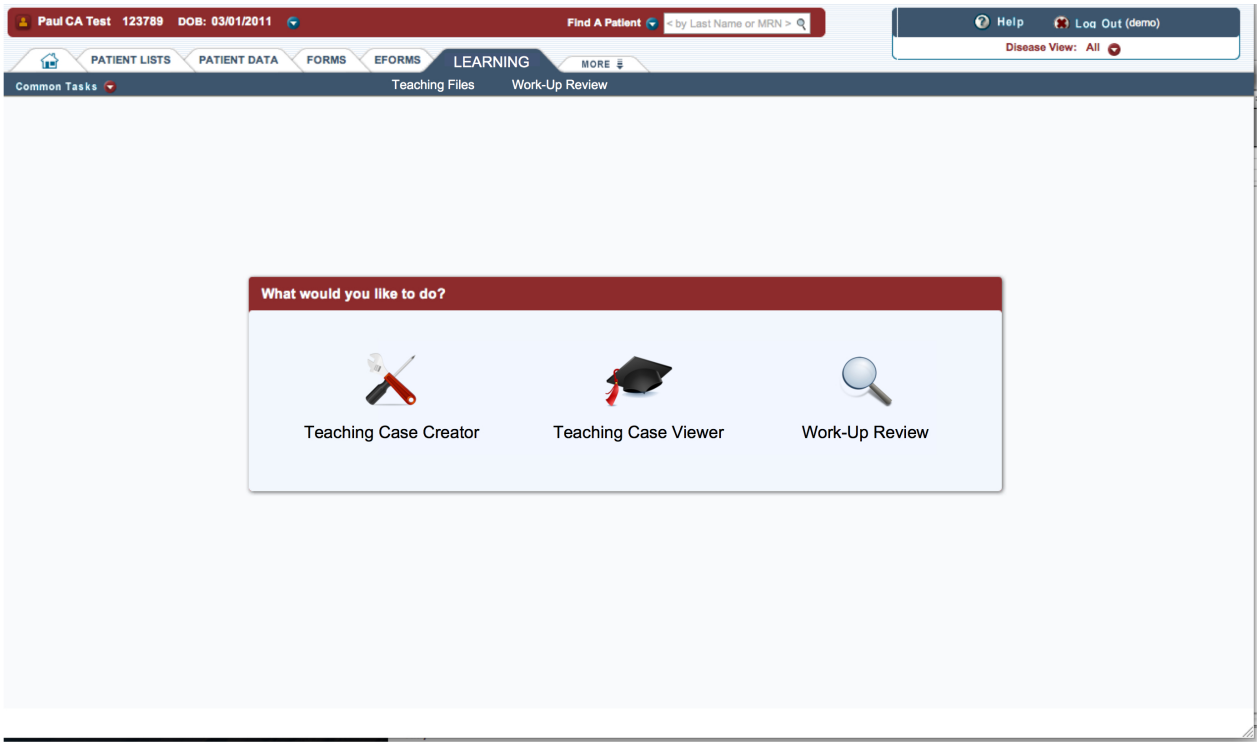

Figure 3: Accessing the BIEMR-LM from CAISIS

5.3.1 BIEMR-LM Teaching Management System

The BIEMR-LM will provide a platform for a TMS that captures and displays selected teaching cases. This system will allow radiologists to quickly and easily create teaching files during their routine clinical workflow. Breast images of interest that are flagged through the BIEMR-CRM or flagged through other review processes in the BIEMR system will be automatically sent to the TMS. The BIEMR-LM will display a worklist of recent patients and allow the radiologist to view the PACS images associated with the case on the adjacent upright monitors at the workstation, and to create a new teaching case or edit an existing incomplete teaching case (Figure 4). Once the command is given to create a new teaching case, the BIEMR-LM Teaching Case Creator user interface will open a template screen that automatically populates with patient data retrieved from the CAISIS database (Figure 5). The radiologist will also be able to choose keyword for the case from a dropdown menu, and there will be a field where they can enter additional information about the case manually.

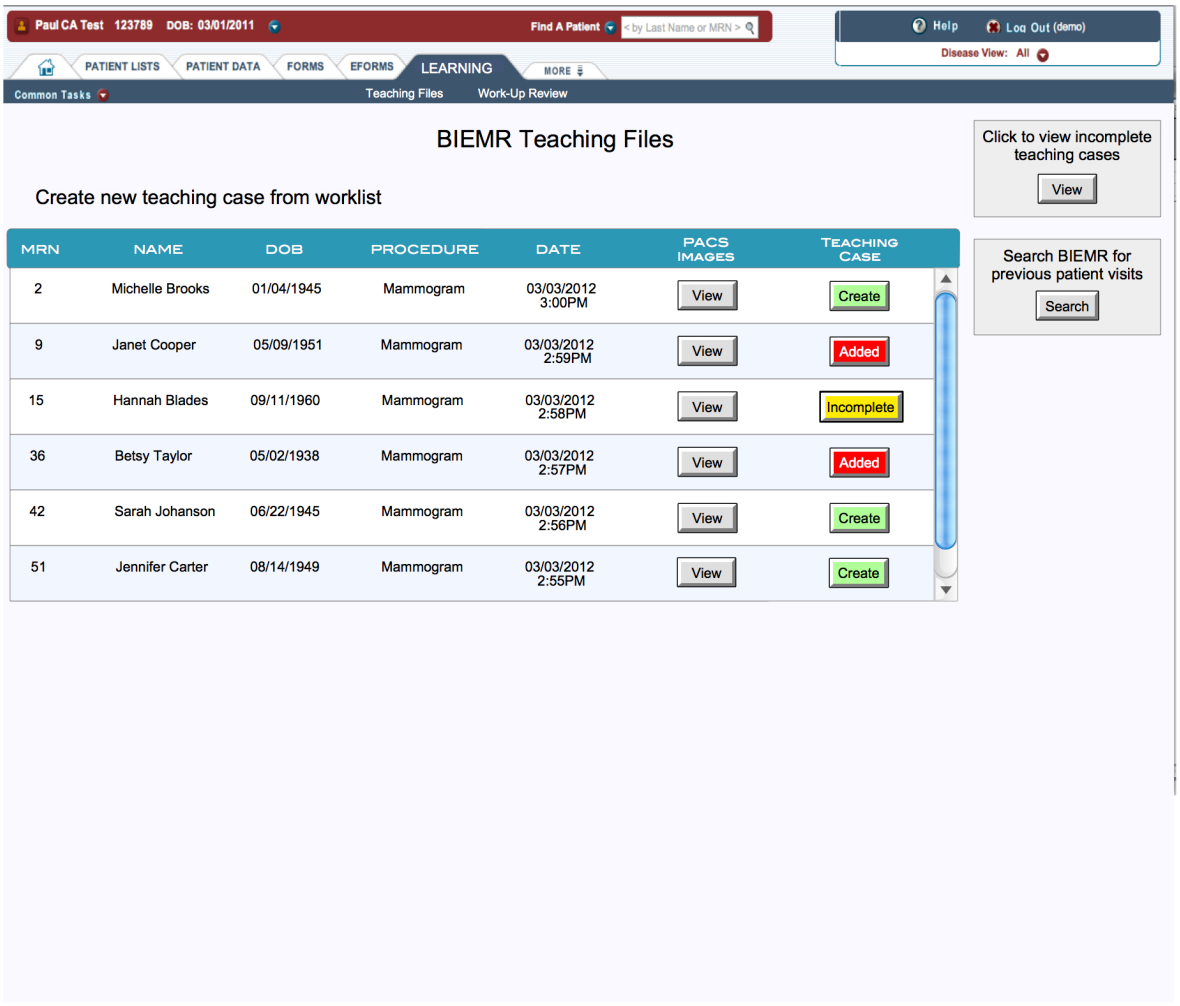

Figure 4: BIEMR-LM Patient Worklist for Teaching Files

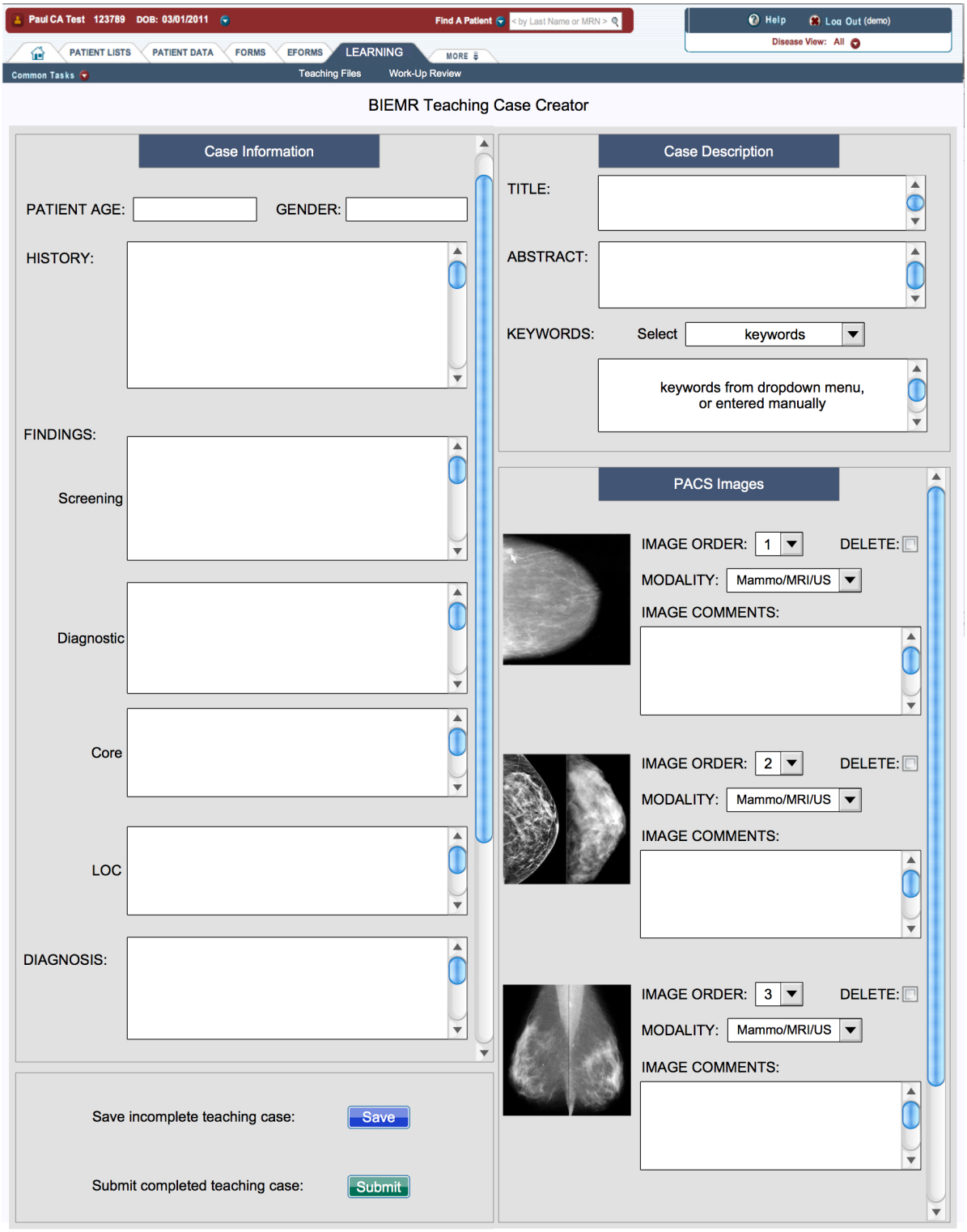

Figure 5: BIEMR-LM Teaching Case Creator

5.3.2 BIEMR-LM Work-up Review System

The BIEMR-LM will provide radiologists and mammography technologists with a work-up review system (WRS) developed within CAISIS that automatically captures and displays specific cases flagged through BIEMR or the BIEMR-CRM. These cases will be available for review by radiologists and mammography technologists, along with access to any other previous work-ups that were performed on a patient. Recent cases will be seen as a patient worklist in the BIEMR-LM WRS and allow for the PACS images to be viewed on the adjacent monitors at the workstation (Figure 6). There will be a search function included for retrieving older cases. Once the command is given to review a work-up, a screen will open with fields for patient information including case history and findings that are automatically populated with data from the CAISIS database (Figure 7). The radiologist or technologist can flag images, add their comments, and determination whether they agree with the initial findings or if the case requires more assessment.

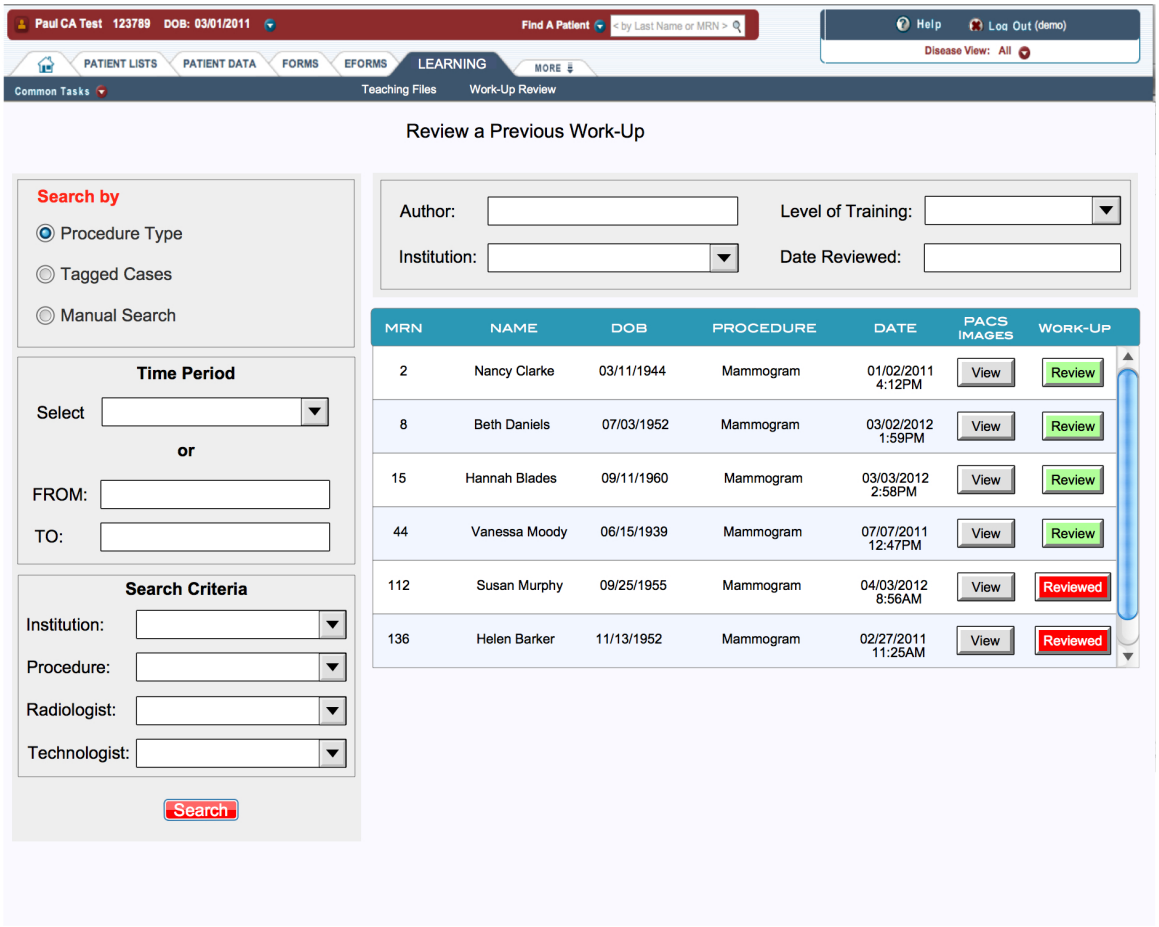

Figure 6: BIEMR-LM Work-up Review Patient Worklist

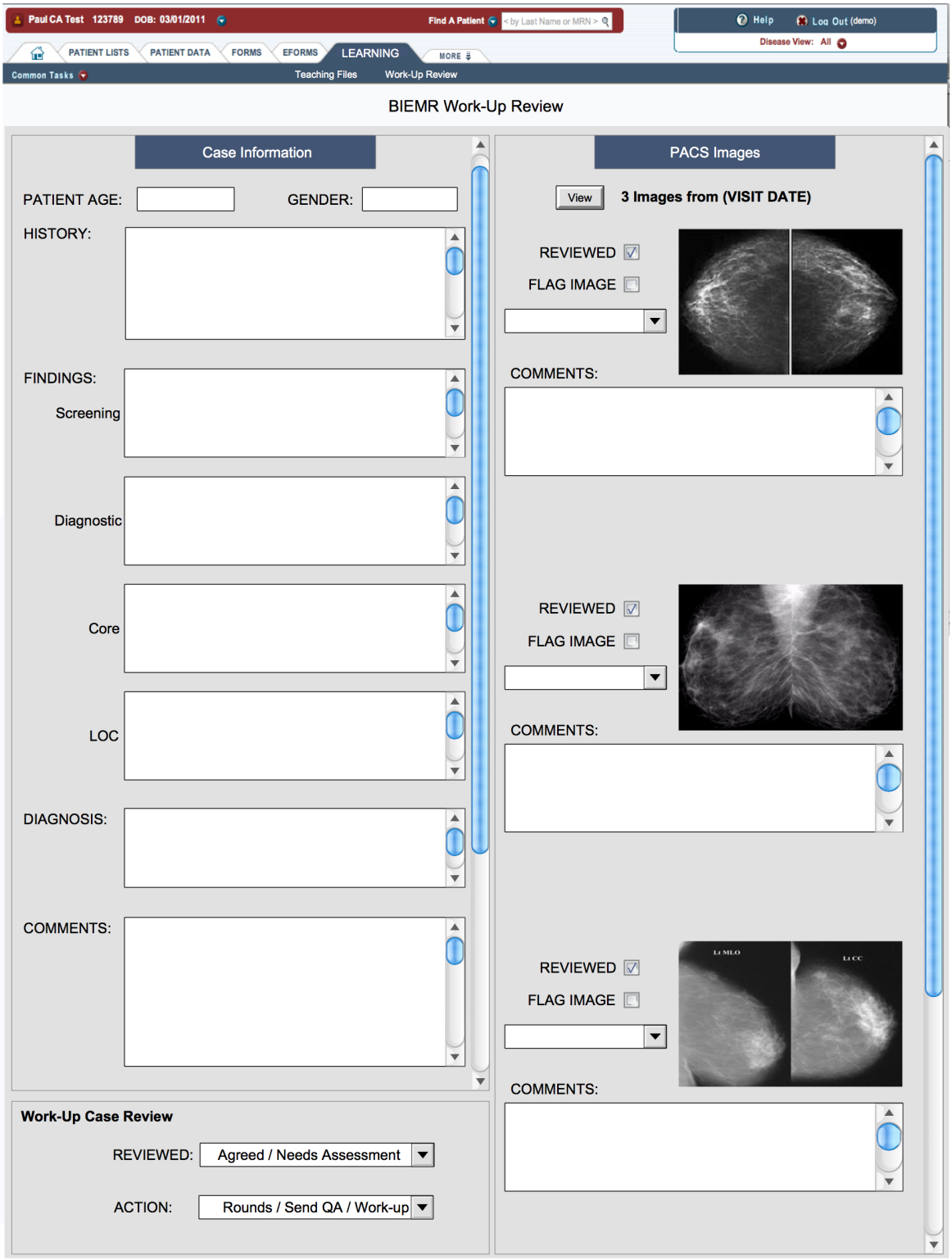

Figure 7: BIEMR-LM Work-up Review Template

6. Conclusions

There exists an opportunity at CDHA to leverage the provincial investment in digital breast imaging technologies by developing and implementing a breast imaging learning module to act as both an educational resource and a self-review tool for radiologists, radiology residents, and mammography technologists to learn from previous imaging cases and review their own performance. Case-based radiology teaching files, which include mammographic images along with information about case history and previous findings and diagnoses, form an important component of radiology education. The BIEMR-LM will give radiologists the ability to easily create teaching files during routine clinical workflow, and through it's integration with the BIEMR system it will provide numerous benefits, including:

- Increased opportunities for radiologist and radiology residents to gain experience by studying interesting breast imaging cases.
- Providing a mechanism for radiologists to receive credit towards their CME for engaging the BIEMR-LM for education and work-up review purposes.
- Streamlining departmental QA workflow by automatically sending a listing of poorly imaged cases to the Quality Control officer.

Open-source software is part of the mainstream and should be given due consideration by any healthcare organization. Having the source code accessible gives users and developers the flexibility to customize the system to meet their needs, and the freedom to make changes in the future as they are required.

7. Recommendations

Moving forward it is recommended to adopt an open-source solution for building the new breast imaging learning module, taking into consideration the long term costs of maintaining a teaching file system and the scarcity of resources available locally. While there are a number of methods by which this could be accomplished using open-source tools such as MIRC and Ilias, it is recommended here that the BIEMR-LM be built from scratch completely within the CAISIS platform. This approach will require more work initially to program and develop the system, but the benefits of this approach will be worth the additional effort required. The system will be designed to meet the requirements of radiologists based on their input and feedback. There is a possibility that once fully developed and implemented, the BIEMR-LM will be chosen by the core CAISIS team in the United States to be included in future releases of CAISIS. The core CAISIS team would then provide the necessary ongoing support to ensure the long term sustainability of the open-source BIEMR-LM.

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Appendix A – Clinical Practice Guidelines for the NSBSP