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I, Yina Du, hereby submit this original work as part of the requirements for the degree of Master of Science in Computer Science.

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A Portable Pediatrics Medical Education Assessment System
for the Pediatrics Milestone Project

by

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M.S. (Northeastern University, China) 2008

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Abstract

Assessment is critically important in medical education. Designing an effective assessment system, however, is very challenging. In this thesis, we developed a portable assessment system based on the Pediatrics Milestone project for fellows and faulty members in Cincinnati Children’s Hospital Medical Center (CCHMC). The Pediatrics Milestone project is a joint initiative the Accreditation Council for Graduate Medical Education (ACGME) and the American Board of Pediatrics to assess resident physicians. Specifically, we first made necessary modification to original assessment framework for real applications on portable devices. Then, our pediatrics medical education assessment system was implemented with cutting-edge mobile technology. iPad from Apple Inc. was chosen by the users as the assessment system platform. Xcode was used for App development. User interface and database were designed on designated integrated development environment. The implemented assessment tool is planned to be used in medical education of CCHMC. With the help of advances in portable devices and applicability of Pediatrics Milestone project, assessment feedback to the students is meaningful and the implemented assessment strategy is anticipated to improve medical education.
Keywords—Assessment System, administrator view, competence, competency, iPad, iOS, implementation of assessment, medical education, Milestones, mobile App, mobile database, resident physicians assessment sub-competencies, the Pediatrics Milestone project, portable assessment system, user interface design, user view design, Xcode.
To my family

for their love, endless support and encouragement.
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Chapter 1

Introduction

1.1 Assessment Systems

Assessment is generally defined as the classification of someone or something with respect to its worth. It is such a common concept for judging whether specific objectives are achieved so that it has been applied in every aspect of our life in many various ways. For example, a driving test is designed to assess if one driver is qualified to drive alone in the future. An exam for a student is performed to assess whether he or she understood the course material. A goodness measure is being done all the time in engineering design to assess if machines will be working correctly or not. Informally, assessment can be treated as measurement of output of any system with or without certain input. Assessment is significant in the case that input or system itself can be adjusted to change output. Otherwise, if output can not be changed, assessment of output is less meaningful. Fortunately, education system is the one that can be improved with effective assessment.

Generally, assessment in education system could be on students, teachers, and even
programs of study. To avoid misinterpretation, we would like to clarify the definition of
the teachers and students as in the book *Problem-based Learning: An Approach to Medical
Education* [1]: 1) Teacher: it refers to anyone responsible for the education of students, for
example, faculty in the college, supervising resident physicians in hospital; and 2) Student:
this refers to anyone engaged in gaining knowledge and skills, such as resident physicians,
all-level students in school, or interns of companies, etc.

Assessing student learning outcome could be performed by exams, interviews or
other observation-based methods. Assessment on teachers could be gained from students’
feedback, or indirectly reflected by students’ performance. Assessment of a program in
education involves broader measurement in many aspects. All in all, assessment could be
applied in every part of education system to improve quality of education so as to eventually
benefit students.

Specifically, assessment on student in education is the process of information ac-
quisition and analysis from diverse sources to understand students’ learning and develop-
ment. [2] It is a significant component in education since it effectively changes the one-way-
street teaching process, which is majorly from teachers to students, to a two-way interactive
learning process. Assessing student learning outcome is very important not only for indi-
vidual student, but also for teachers and programs.

For students, assessment is able to help individual student to gain insight into
their understanding of knowledge and skills. [3] Students can actively and frequently assess
their current status of understanding so that adjusted strategies could be made timely for
learning performance improvement.
For teachers, assessment can certainly be used to improve teaching strategies. A good teacher should know how to check their teaching progress and evaluate their efforts. Assessing students’ learning could provide meaningful information to teachers about their own teaching style, the pace of teaching, difficulty levels of material for specific student. All of those information can be used for future teaching improvement.

For programs, assessment could help programs to achieve their missions effectively. Assessment on students is a critical part of the evaluation of programs. Assessment results could help programs to adjust curriculum setting, course material, learning environment and many other aspects. All those information could be analyzed in order to make an improvement plan for the programs. In short, assessment is so important for anyone in the educational system so that how to design an effective assessment method is a major issue for education nowadays.

Since effective assessing students is critical to improve our education, numerous literature have been published to address the effective assessment design. Regional accrediting agencies have integrated assessment activities on student learning outcomes into their criteria. Also, many states have made the effective assessment as mandatory. All those efforts on assessment activities explicitly indicate that significance of assessment have been widely accepted. On the other side, all those efforts also implicitly gave us a message that designing an effective assessment is a challenging issue.

In this thesis, an assessment system is defined as a set of assessment strategies and their corresponding assessment scope in the educational material for a specified education background. For example, the SAT is a globally recognized college admission exam, and
it is designed specifically for students with high school education background. The exam method (written exam) and its corresponding assessment scope are all suitable for assessing a high school level students. Test of English as a Foreign Language (TOEFL) is a English test designed for international students whose mother tongue is not English, so one of its assessing method (listening and speaking part) is an effective way to assess those international students’ ability to study in an English learning environment. As described above, the SAT and TOEFL are two assessment systems for different education backgrounds. Those two systems not only have different test materials, but also assessing strategies, because of the different backgrounds of the test takers.
Although various assessment systems for different purposes may vary, some theory frameworks exist to guide the effective assessment system design. A theoretical *Assessment Cycle* can be illustrated in Fig. 1.1, which is redrawn based on Maki’s book *Assessing for learning: Building a sustainable commitment across the institution* [7]. The *Assessment Cycle* includes five components: Objectives, Expected Outcomes, Actions, Actual Outcomes and Assessment. First, objectives must be clearly defined. Then, expected outcomes could be defined according to defined objectives. Next, educational actions can be taken to achieve expected outcomes, and actual outcomes are results from actions. The actual outcomes, namely student learning outcomes, may be different from what expected. Thus, a assessment plan should measure the actual outcomes accurately and bring all those feedback to improve related activities.

This *Assessment Cycle* gives us a outline that how to start a assessment system design for improving our education. Designing an effective assessment system is certainly a easier-said-than-done mission. First of all, to design an effective assessment system, objectives and expected outcomes must be defined clearly at the beginning. Strictly speaking, objectives and expected outcomes are not within the assessment system, but they are indeed the ground for assessment system design to move forward. To define both objectives and expected outcomes, one education background needs to be specified. Objectives and expected outcomes vary a lot based on education background. Education background involves education areas, education level, characteristics of students, and etc. All these factors must be considered before design since different background certainly lead to different objectives and expected outcomes. For example, one same math exam might not be proper
to assess students from engineering majors and mathematics major because of different educational objectives and expected outcomes. Therefore, background must be specified to set corresponding objectives and expected outcomes before the assessment system design.

With educational objectives and expected outcomes, we can start designing a practical assessment system. To effectively measure actual outcomes, we need appropriate assessing strategies and assessing material scope. As an example, in TOEFL, test takers are asked to listen a mock conversation on a U.S. university campus or record their speech on specific topics into computers. These are the good examples in an effective assessing strategy design, because the assessing activities create a simulated U.S. university environments and place test takers into those environments, then, the test results would accurately reflect the possible performance of those students on the U.S. university campus in the future. The strategies and scope are very different across different assessment systems, so there are no simple rules. But, the number of assessing strategies is often limited, and the commonly used strategies utilized everyday include written exam, practical project, interviews. Thus, design of strategies and materials scope can be learned from experienced educators.

Finally, the most difficult part is that assessing results from an effective assessment system should be meaningful and helpful for everyone involved to set improvement plan. Most written exam cannot meet this requirement, since the making the questions based on assessing material is actually a sampling procedure. The assessment scope in a certain exam may or may not cover the weakness of a certain student. Also, since students normally have not enough ability to analyze the scores and figure out a useful improvement plan without help of professional consultant, any given scoring system can hardly achieve this ultimate
goal of assessment system. This fact will break the link between "Assessment" and "Action" in Fig. 1.1 so that the assessing feedback are actually not being utilized effectively.

In summary, a good assessment system is one critical component in education. It completes the interaction of teachers and students so as to make educational activities advance. However, design of an effective assessment system is very challenging, especially making assessment results meaningfully to students, teachers and programs.

1.2 The Pediatrics Milestone Project

Pediatrics Milestone project is such an effort to design an effective assessment system in medical education community. The Pediatrics Milestone Working Group contributed countless hours in assessment design, not only trying to establish a standardized system for assessing resident physicians, but also to make assessment results benefit both resident physicians and their supervisors.

From a technical point, our portable assessment system could be utilized in any circumstance. But, in this thesis, we would like to choose the Pediatrics Milestone project as our carrier, because 1) the Pediatrics Milestone project is an excellent effective assessment system example in education community; 2) the Pediatrics Milestone based assessment system is planned to be used in practice to assess the performance of resident physicians in Cincinnati Children’s Hospital Medical Center (CCHMC), a top-3 children’s hospitals in U.S.

The Pediatrics Milestone project is a joint initiative, launched in early 2009 by the Accreditation Council for Graduate Medical Education (ACGME) and the American Board
of Pediatrics (ABP), to assess resident physicians in the context of their participation in ACGME accredited residency. [8,9]. Prior to the Pediatrics Milestone project, a *Assessment Toolbox* has been offered to medical education community by ACGME Outcome Project. However, institutions of medical education still have the difficulty to measure quality of resident physicians in an efficient manner. [10] Thus, the Pediatrics Milestone project was launched to advance outcome assessment in medical education.

The objectives of medical education is that the students, namely physicians, should be capable of evaluating and managing patients with medical problems effectively, efficiently, and humanely. [1] To effectively assess a resident physician, in the Pediatrics Milestone project, competencies and sub-competencies were defined to reflect general attributes of a qualified doctor. In fact, the purpose of setting competencies and sub-competencies is same as defining objectives and outcomes in *Assessment Cycle* theory. Furthermore, developmental Milestones were defined as the benchmarks of knowledge, skills, and attitudes to measure where the resident physicians are during the learning process. Milestones are a series of observable developmental phases, marking a resident between novices and experts. Note that the Pediatrics Milestone project design a comprehensive framework to assess residents physicians, however, for a specific group of resident physicians or medical students, assessment scope may be chosen considering the education background. Assessment scope is a subset of competencies, sub-competencies, and Milestones to assess the attributes of resident physicians in a specific background.

The significance of the Pediatrics Milestone project is obvious, since realization of Milestones fundamentally changed the assessment system from evaluating whether a resi-
dent physician is qualified to performing a comprehensive assessment for current state of attributes of the resident physicians. All the assessment results are meaningful for residents to understand both their strength and weakness. The Pediatrics Milestone project based assessment tool is anticipated to become the standard assessment system in medical education. Therefore, implementation of the Pediatrics Milestone assessment system is not only a critical practice of utilizing portable devices platform for assessment, but also a meaningful effort on establishing a real assessment system for medical education. Significance of the Pediatrics Milestone project has been widely acknowledged in many literature, so we would not repeat that. Please note that the focus of our work in this paper is the implementation of a assessment system on portable devices with minor modification of the framework according to system users.

1.3 Contributions and Organizations

To end this chapter, we would like to emphasize our contribution in this project. Our group is led by Dr. Chia Han, University of Cincinnati (UC) and Dr. David Dewar, MD, CCHMC. We developed a portable assessment system based on the Pediatrics Milestone project. Specifically, we made necessary minor modification to Milestone framework in the Pediatrics Milestone project, and implemented the whole assessment system with cutting-edge portable device technology. The implemented assessment system is planned to help assessment of resident physicians in CCHMC.

Our contributions in this thesis can be summarized as follows:

1. Modifying the Milestone framework of the Pediatrics Milestone Project in prepara-
tion of a practical assessment system for CCHMC. Some Milestones in the Pediatrics Milestone Project are not explicitly defined, and need further refinement based on the requirement of individual medical education institution. Thus, based on CCHMC users’ request, we made minor refinement on the Milestone framework.

2. Designing user interface and database of the assessment system and implementing it on the portable device platform. iPad devices were chosen as our assessment system platform by CCHMC users. Xcode was used on Mac Pro to develop a user-friendly error-proof assessment APP.

The rest of the thesis is organized as follows: Chapter 2 introduces background of medical education & assessment and portable devices technology. Chapter 3 elaborates the Pediatrics Milestones assessment system. In Chapter 4, implementation of assessment system on a Apple device platform is described. Finally, Chapter 5 summarizes our work and describes possible directions of our future works.
Chapter 2

Background

2.1 Medical Education and Assessment

Medical education in many counties is quite different from education for other careers, due to its critical impact to people’s life and death in our society. Commonly, before full registration is granted, resident physicians have to first go through 4-year undergraduate education (commonly in Science), and then join a medical school, which takes 3-4 years, followed by several years residents practice training. The whole duration of medical education taken by a licensed physician commonly is at least ten years. Such a long term education requirement is designed to guarantee the quality of medical practitioners. In this medical education progress, assessment becomes of critical importance for students, schools, hospitals, and particularly patients.

The assessment of clinical performance of medical students is critically important in the confirmation of appropriate progress through the curriculum. [11] During the past several decades, there has been rapid and extensive changes in the way that medical education
activities are conducted. [12] So, there is no doubt that assessment schemes also continue
to change. Several new methods of assessment have been developed and implemented over
this time and they have focused on clinical skills, interpersonal and communication skills,
professionalism and so on. [13]

During early stage of education, the medical knowledge and clinical skills of medical
students could be evaluated using written and oral examinations. The written examina-
tions are usually composed of questions based on critical medical knowledge, while the oral
examinations typically involves open-ended questions, and require students to present their
thoughts.

In advanced phase of education, there are two common subjective assessment
schemes: clinical simulation and clinical observation. In clinical simulation, students are
required to go to a standardized patients’ (actors) bedside, gather information, and then
present a diagnosis and treatment plan to evaluators who will make judgments about the
performance. This clinical simulation scheme has been part of the U.S. Medical Licensing
Examination since 2004. [14]

In clinical observation, supervising physicians would assess the students or resi-
dent physicians over a specific period. The assessment based on both direct observation and
indirect observation. While direct observation need supervisors to observe the interaction
between students and patients, indirect observation involves all other multi-source informa-
tion acquisition. Despite of issues such as subjectivity, this is still the most common and
effective assessment scheme.

Traditionally, each medical institution have their assessment form which need su-
supervising physicians to fill in after observation. No standards are set for the whole community. As early as 1999, ACGME initialized the 10-year Outcome Project. They defined 6 competencies and a Assessment Toolbox has been offered to medical education community. However, institutions of medical education still have the difficulty to measure quality of resident physicians in a efficient manner. [10] Thus, the Pediatrics Milestone project was launched to advance outcome assessment in medical education. In the Pediatrics Milestone project, direct observation is still one of the most important assessment scheme. Supervising clinicians could assess the students and fill out the standardized assessment forms after the observation, or carry a form with them and finish it during observation. From ancient time, people start using this written form manner for information acquisition. However, modern portable devices have advancing the information recording process with improved effectiveness and efficiency.

2.2 Portable Devices Technology

In this era of mobile technology, portable devices, also called mobile devices, have tremendously impacted our living style. Those portable devices, such as smart phone and tablet, are the most fascinating devices that we use the most. More and more people put their effort into mobile computing and wireless network. Now there are over 900,000 applications in Apple Store by June 2013 based on Apple announcements. [15] These applications satisfied all kinds of needs such as entertainment, education, news, finance, medical, etc.

Portable devices development can be traced back to 1968, where Alan Kay described one portable personal information manipulator. [16] IBM 5100 is the first portable
computer on the market in 1975. [17] Since then, portable computers went on a high way of fast technique improvement. Nowadays, portable computer is not a specific enough term to describe any device, since this term has been extended into several different directions. Laptop is used to referred full-size portable computer, whose computing power is emphasized, and weight of the machine is relative heavy. Netbook is a new emerging term for lighter, smaller version of laptop, whose computing power is normally less than full-size laptop. However, new launched product chromebook from Samsung and Google fully relies on internet service so that even a operating system is not needed anymore. With possible combination of cloud computing, netbook has a bright future. Ultrabook is concept used for light weight laptop with top-class hardware. Computing power is excellent even though smaller size and lighter weight are its features.

Speaking of portable devices, we have to mention a mobile industry leap led by Steve Jobs and his Apple Inc. Apple’s smartphone product iPhone was released on June 29, 2007. The iPhone integrates portable computer concept into the cellphones by using 3.5 inch touch screen instead of combination of small keyboard and small screen setting. iPhone is the origin of the mobile technology blast. Apple continues to release its pioneer tablet product iPad on April 3, 2010. With a 10 inch touch screen, iPad is able to provide a large view for more complex tasks, such as our assessment system. iPad also has many other features, such as decent computing capability, wireless communication, mobile database management, and so on. More details could be found on Apple website. [15]

Generally, the common features of these mobile devices are: (1) portability (2) timeliness (3) intelligence.
(1) **Portability:** Portability is certainly a requirement for all this mobile devices. Now many different size of devices are on the market so that they can be used everywhere anytime. Given this high portability of mobile devices, people could listen to the music during workout with smartphone tied on their arm. For the work without computer at hand, these portable mobile devices could help them save their work data or log easily into the server drive and avoid shortcomings of working on paper.

(2) **Timeliness:** With the access to wireless network, mobile devices transmit and exchange data with application host server in the background so that they could fetch first hand news and information which based on your setting or update your information into the server in real time.

(3) **Intelligence:** With ability of computing and installation of sensors, mobile devices has evolved into smart devices assisting mobility, manipulation, perception, and cognition. It can change screen vertically or horizontally depends on the way you hold it. It can warn you of personalized assessment by sensing the body temperature, pulse and heart rate. This personalized assessment is coming from the optimized result of a computational model which is constructed by reasoning algorithms and data mining.

Ignited by iPhone, the software aspect of mobile device industry is also booming. App is a newly defined term used by Apple for mobile application running their devices. As the users of mobile devices increasing dramatically in such a short time, traditional software companies are not capable of handling such a huge request. A large number of small companies or even individuals joined the mobile App development industry. Apple provides a developmental tool Xcode for their App development so that developers don’t
need to start from the sketch. [18] The integrated development environments (IDEs) such as Xcode lower the entry requirement of software application developers. As a reward, large number of talent developers have created numerous mobile Apps to satisfy different requirement of the mobile users.

Different Apps have their own features to serve the context. Social network applications provide several ways of communications (post photos and messages, attach files and start video chat). Game applications focus their features on fancy layout design and finger-driven multi-touch interface. In this way, we also provided a iPad-based App to serve as a portable medical education assessment system.

2.3 Motivation: When Assessment Meets Portable

Although these devices have dramatically change the way of our living, one can still argue that portable devices only change one small part - data acquisition - in the education assessment. We believe that the fact is this small change makes the whole assessment process effective.

All educational institutions faces a problem of how best to inform students about their performance. Objectivity, detail, and timeliness are essential components of performance evaluation, but are challenging to achieve in a clinical setting where students are exposed to several different services and have brief interaction with a number of different patients and attend physicians with a short time span. Although clerkships and clinical rotation has been developed to achieve high-quality ongoing performance evaluation and feedback to student, it seems that evaluation for medical education lacks of effectiveness and
effective strategies. In addition, the feedback data is still not helpful to students, although quantitative evaluation scales is developed.

The Pediatrics Milestone project is launched to improve the assessment system for medical students or resident physicians. In the project, Working Group develops a number of competencies and sub-competencies plus their corresponding Milestones. These benchmarks are efficient and effective for assessing the students practically. However, one disappointed fact is that when we printed them on the paper with common size font (Calibri, 11 points), it needs 32 pages paper, and this is only for one student. In such a fast speed hospital environment, we highly doubted the applicability of traditional paper-based form format assessment method. It is impractical for any supervising physician to carry a stack of assessment forms to observe several resident physicians. This really motivates us to develop a assessment system with IT technology in a more practical method.

In this way, advantage of mobile devices are obvious for our assessment system. Our App on portable devices is able to provide portability, timeliness and intelligence to users where traditional methods cannot provide. One mobile device is enough for all assessment related tasks. With our App, users can quickly locate and edit assessment categories for different students. By using wireless internet, assessment results could be sent to students timely. Therefore, although our portable system is only a data collection step within the whole education and assessment procedure, we believe it fully unleash the usefulness of the Pediatric Milestone project.
Chapter 3

The Pediatrics Milestone Assessment System

In this chapter, assessment content of portable Pediatrics Milestone assessment system was described. First, competencies and sub-competencies of the Pediatrics Milestone project were introduced. Second, we described Milestones framework for assessing the status of resident physicians. Finally, modified part of Milestones framework was elaborated.

3.1 Competencies and Sub-competencies

Competencies and sub-competencies are defined in the Pediatrics Milestone project to assess the general attributes of a resident physician. In fact, the concepts of competencies and sub-competencies are very similar to objectives and outcomes in Assessment Cycle theory. Competencies are originally defined very general. It reflects the general objectives of medical education. Each competency requires that a qualified physician should have the
Table 3.1: Competencies

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<th>IDs</th>
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<tr>
<td>A</td>
<td>Patient Care</td>
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<tr>
<td>B</td>
<td>Medical Knowledge</td>
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<tr>
<td>C</td>
<td>Practice-based Learning and Improvement</td>
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<tr>
<td>D</td>
<td>Interpersonal and Communication Skills</td>
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<tr>
<td>E</td>
<td>Professionalism</td>
</tr>
<tr>
<td>F</td>
<td>System-based Practice</td>
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<tr>
<td>G</td>
<td>Personal and Professional Development</td>
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competence in different aspects. For example, the first category of competencies is Patient Care, so it sets the objective of a physician as have the competence to provide patient care. All the competencies are listed in Table 3.1. As you can see, competencies are very general concepts in the Pediatrics Milestone project, which are common for the objectives in any project. In some way, competencies are simply some separated domains for assessing the ability of any student. Such general competencies are lack of the practicality to assess a resident physician so that sub-competencies are also defined in the project.

Compared to competencies, sub-competencies are designed as some specific knowledge and skills to achieve the competencies. Therefore, different from general concept, sub-competencies are very practical and feasible for assessment. As an example, we list the sub-competencies of competency C: 'Practice-based Learning and Improvement' as in Table
3.2. While competency C only defined areas in practice-based learning and improvement, all the sub-competencies further gave us specific requirements such as set improvement goals, participate in the education of patients, and incorporate feedback into daily practice. Those sub-competencies actually clearly define some activities of resident physicians that could be observed by supervisors. In this way, sub-competencies function as expected outcome in Assessment Cycle theory, since sub-competencies are very specific in term of assessing a student. Whether a resident physician has the sub-competencies could decided clearly by observation. Therefore, sub-competencies make the assessment practical and competencies clearly organize the assessment areas.

3.2 Developmental Milestones

In this part, we would like to introduce the Developmental Milestone in the Pediatrics Milestone project. The merit of the Pediatrics Milestones project is that it assesses not only whether a student is qualified, but also where a student is in the education progress. Competencies and sub-competencies are already very specific in term of deciding if a resident physician is a qualified doctor by observing his or her state of being. Furthermore, Developmental Milestones were defined as the benchmarks of knowledge, skills, and attitudes to measure where the resident physicians are during the learning process. Milestones are a series of observable developmental phases, marking a resident between novices and experts. The Milestones turned a simple evaluation into a comprehensive assessment by providing meaningful and guide-oriented feedback to the students. Based on the feedback generated from Milestones, the resident physicians being assessed could understand that
Table 3.2: Sub-competencies of C: Practice-based Learning and Improvement

<table>
<thead>
<tr>
<th>IDs</th>
<th>Sub competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Identify strengths, deficiencies, and limits in ones knowledge and expertise</td>
</tr>
<tr>
<td>C2</td>
<td>Set learning and improvement goals</td>
</tr>
<tr>
<td>C3</td>
<td>Identify and perform appropriate learning activities to guide personal and professional development</td>
</tr>
<tr>
<td>C4</td>
<td>Systematically analyze practice using quality improvement methods and implement changes with the goal of practice improvement</td>
</tr>
<tr>
<td>C5</td>
<td>Incorporate formative evaluation feedback into daily practice</td>
</tr>
<tr>
<td>C6</td>
<td>Locate, appraise, and assimilate evidence from scientific studies related to their patients health problems</td>
</tr>
<tr>
<td>C7</td>
<td>Use information technology to optimize learning and care delivery</td>
</tr>
<tr>
<td>C8</td>
<td>Develop the necessary skills to be an effective teacher</td>
</tr>
<tr>
<td>C9</td>
<td>Participate in the education of patients, families, students, residents, and other health professionals</td>
</tr>
<tr>
<td>C10</td>
<td>Take primary responsibility for lifelong learning to improve knowledge, skills, and practice performance through familiarity with general and experience-specific goals and objectives and attendance at conferences</td>
</tr>
</tbody>
</table>
what are their strength and what are their weakness, what aspects should be improved to become a qualified or excellent physicians.

Let us use an example to show how Milestones help assessing the learning progression of resident physicians. Table 3.3 listed the Developmental Milestones of sub-competency B1: Demonstrate sufficient knowledge of the basic and clinically supportive sciences appropriate to pediatrics. To reflect different phases of learning progression, these Milestones for sub-competency B1 started scale of knowledge related ability from 'B1.1 Does not know or remember knowledge’, which is certainly not a qualified state of doctor. Then, the progression went through four middle phases from 'B1.2 Understand knowledge, but still learning to apply’, 'B1.3 Understand knowledge, and apply’, 'B1.4 Analyze knowledge for diagnosis’, to 'B1.5 Evaluate knowledge and use it appropriately’. Finally, the B1.6 Milestone for a physician is to learn from experience and apply information for new situations. Although we all hope the doctor to be perfect in our real life, B1.3 could be a minimum requirement for a medical student to be qualified doctor, B1.4 is a phase where we can rate the doctor as good, and with Milestone of B1.5, the physician being assessed has been an excellent doctor in term of this specific sub-competency. More Milestones information could be found in the Pediatric Milestone project document at ACGME website. [19]

3.3 Minor Modification of the Milestones

As mentioned in Chapter Introduction, Competencies, Sub-competencies, and Milestone are a framework defined by ACGME and ABP. Therefore, in a real assessment for a specific group of resident physicians, not all the assessment framework need to be fin-
Table 3.3: Milestones of B1: Demonstrate sufficient knowledge of the basic and clinically supportive sciences appropriate to pediatrics

<table>
<thead>
<tr>
<th>IDs</th>
<th>Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1.1</td>
<td>Does not know or remember the basic content knowledge of common pediatric problems and illnesses</td>
</tr>
<tr>
<td>B1.2</td>
<td>Understands the basic content knowledge of pediatrics, but is still learning to apply it to clinical situations</td>
</tr>
<tr>
<td>B1.3</td>
<td>Understands the basic content knowledge of pediatric practice, and is able to synthesize and apply it in a clinical situation</td>
</tr>
<tr>
<td>B1.4</td>
<td>Able to analyze and categorize knowledge in a way that allows the generation of a meaningful differential diagnosis</td>
</tr>
<tr>
<td>B1.5</td>
<td>Able to evaluate knowledge and use it appropriately in a given clinical encounter to develop meaningful clinical management plans</td>
</tr>
<tr>
<td>B1.6</td>
<td>Learns from experience; analyzes a situation, evaluates what worked well and what did not work well in the past, and creates, adapts, or extrapolates information appropriately to new clinical situations and encounters</td>
</tr>
</tbody>
</table>

ished at once. Also, based on requirements of different educational institutions and different background of the students, modified sub-competencies and Milestones may be needed dur-
ing practical assessment. In our project, according to users’ opinion in CCHMC, we made minor modification to the original framework of assessment items. In this section, we would like to elaborate our modified Milestones.

First, we made some modification on sub-competency A5: Perform complete and accurate physical examinations. In the original framework, Milestones are provided for three types: the Psychomotor performance of the physical exam, the approach to the pediatric physical examination, and the approach to the focused physical examination. However, based on the background of CCHMC and the possible student background, users prefer only one specific type Milestones. Thus, we made necessary modification and merge some assessment benchmarks from all three types of original Milestones into a new integrated Milestones. Here, we provided our modified version of Milestone as in Table 3.4.

Second, when we were working on sub-competency A8: Prescribe and perform all medical procedures, we found project document only provides a table-like developmental continuum. Since our system is deployed as a App on the mobile devices, the assessment format, namely List-format, is not flexible as printed assessment forms to change back and forth. Users also prefer to the consistency of one format so that assessment would not be disturbed in the rapid speed. Thus, we modified the original table-like continuum into a ordered developmental Milestones as shown in Table 3.5.

Finally, for A13: Provide appropriate supervision, framework listed very detailed benchmark in each items of Milestones. Again, based on the background of CCHMC, we worked with users to refine the original Milestone to a simple version. We also listed the modified version as in Table 3.6.
In sum, based on users’ requirement or format limitation, we made necessary minor modification to the original Milestones of the project. The most of Milestones for assessment are kept as same as original version.
<table>
<thead>
<tr>
<th>IDs</th>
<th>Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5.1</td>
<td>Performs physical exam maneuvers incorrectly or does not change the physical exam based on child’s developmental level or based on presenting complaint and diagnostic hypothesis</td>
</tr>
<tr>
<td>A5.2</td>
<td>Can perform basic physical exam maneuvers correctly yet does not routinely recognize abnormal findings. May sometimes modify exam to be developmentally appropriate. Exams children with a broad diagnostic hypothesis using a head-to-toe approach.</td>
</tr>
<tr>
<td>A5.3</td>
<td>Correctly performs basic physical exam maneuvers and correctly recognizes and interprets abnormal findings. Consistently uses a developmental appropriate approach when examining a child and uses a narrow list of diagnostic hypotheses and completes the physical exam evaluating for positive and negative findings of only the most relevant diagnostic considerations.</td>
</tr>
<tr>
<td>A5.4</td>
<td>Performs, elicits, recognized and interprets the findings of most physical exam maneuvers correctly. Maximizes cooperation of the child and caregiver in approach to physical exam. Focuses on key physical exam findings to discriminate between competing similar diagnoses.</td>
</tr>
<tr>
<td>A5.5</td>
<td>Performs, elicits, recognized and interprets the findings of even special testing physical exam maneuvers correctly. Maximizes cooperation of the child and caregiver in approach to physical exam. Focuses on key physical exam findings to discriminate between competing similar diagnoses.</td>
</tr>
</tbody>
</table>
Table 3.5: Milestones of A8: Prescribe and perform all medical procedures

<table>
<thead>
<tr>
<th>IDs</th>
<th>Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td>A8.1</td>
<td>Demonstrate anatomy &amp; Physiology</td>
</tr>
<tr>
<td>A8.2</td>
<td>(Besides A8.1) Identify indications &amp; Benefits</td>
</tr>
<tr>
<td>A8.3</td>
<td>(Besides A8.2) Identify contra-indications &amp; risks</td>
</tr>
<tr>
<td>A8.4</td>
<td>(Besides A8.3) Able to provide informed consent</td>
</tr>
<tr>
<td>A8.5</td>
<td>(Besides A8.4) Able to handle pain management and patient psychological preparation</td>
</tr>
<tr>
<td>A8.6</td>
<td>(Besides A8.5) Able to interpret results (of labs on specimens; of post-procedure radiographic images; of therapeutic changes)</td>
</tr>
<tr>
<td>A8.7</td>
<td>(Besides A8.6) Able to analyze checklist driven task</td>
</tr>
<tr>
<td>A8.8</td>
<td>(Besides A8.7) Anticipates complications and manages those complications, ongoing monitoring and assessment of patient with escalation of care as needed and communication of status with family and care team</td>
</tr>
</tbody>
</table>
Table 3.6: Milestones of A13: Provide appropriate supervision

<table>
<thead>
<tr>
<th>IDs</th>
<th>Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td>A13.1</td>
<td>Limited experience as supervisor demonstrated by difficulty stepping back from direct care</td>
</tr>
<tr>
<td>A13.2</td>
<td>Recognizes need to trust those being supervised but cannot accurately assess level of competency for that learner</td>
</tr>
<tr>
<td>A13.3</td>
<td>Can assess learners competency and align amount of supervision to learners needs but still is too hands on in direct care &amp; risks</td>
</tr>
<tr>
<td>A13.4</td>
<td>Accurately assess both competence and capability of learner while balancing trainee’s need for independence with patient safety</td>
</tr>
<tr>
<td>A13.5</td>
<td>Maximizes the balance between trainee’s professional growth and need for patient safety and adjust supervision as necessary</td>
</tr>
</tbody>
</table>
Chapter 4

Implementation of the Assessment System

In this chapter, we would like to elaborate the implementation of our portable assessment system. First of all, we introduced basic hardware and software information of our development platform. Then, we described the design for the database. At the end, design of user interface in our assessment system was elaborated.

4.1 App Development Platform

We would like to first introduce basic specifications of our portable device hardware and development platform for software in this part. In this project, Apple’s iPad is the designated portable device for the assessment system based on the users opinions. As the pioneer of the tablet technology, iPad includes the most advanced hardware technique and stable software performance. Most importantly, 10 inch touch screen of iPad is desirable for
such an software application, since Milestone description is relatively long, and Milestones with proper size font occupy too much screen space on other smaller size devices.

On mobile devices, a software application is referred to as an App. Our assessment system is also developed as an App for iPad. For our assessment App, Xcode, an integrated development environment (IDE) developed by Apple for software developers around the world to develop App for Apple operating system, was used. The version of Xcode we used is 4.1. To run Xcode, we were using one Macbook Pro with Mac OS X 10.7. With such a configuration of development tools, an assessment App is successfully developed on iPad device with iOS 5.1.

Despite of many technique difficulties during App development, we would like to introduce basic database design and user interface design in this thesis.

### 4.2 Database Design

Database design is an important component in the App development process. Our assessment system is essentially a data acquisition tool for supervising physicians to collect the performance data of resident physicians. Thus, data management is the core of our system.

Although there are several different technical aspects of database between mobile devices and desktop devices, theoretic aspects of database are still identical. Fig. 4.1 is a Entity-Relationship diagram to demonstrate the relations for our database. [20] Totally, we have 4 entities: Student, Assessment, User, and Assessment Category.

**Student entity:** For this entity, we have a key attribute-Student ID, and four
other attributes- Active, Name, Email, Current Year. These information are used to describe a medical student or resident physicians identity.

**User entity:** For user entity, we have user ID (key attribute), User Name, phone, Active, and Email (attributes). This entity is defined for administrator, who coordinate the assessment in the medical institutions, and supervising physicians who observe students during assessment.

**Assessment category entity:** This entity is used to maintain the competencies, sub-competencies, and Milestones information. We have a Category ID as key attribute. Other attributes include Section ID, Section Name, Objective, and Active. This entity works as a pool of all categories to be assessed.

**Assessment entity:**

We defined key attribute as Assessment ID. Other attributes include Data, Active, Context Info. This one is for a specific assessment task. In context info, it involves assigned certain competencies, sub-competencies, and Milestone, which is a subset of items from Assessment category entity.

Relationship between these entities has been clearly shown in Fig. 4.1. The Assessment Result and Assigned Category are two relations to connect all entities. Assessment result as a relation connects three entities: one User, one Assessment, and multiple Students, while relation Assigned category involves one user and multiple Assessment categories.

In the practical implementation, multiple tables in the database are used to store information about users, students, and assessment category (Competencies, sub-competencies, and Milestone). Other result tables are generated based on relationship between entities in
4.3 User Interface Design

In the following part of this section, we would like to illustrate our user interface design with major views of our assessment system. User interface of our system are designed as different views in the App for specific tasks. A hierarchical tree for user interface is demonstrated in Fig. 4.2.

One view of App may involves buttons, context input window, sliders, or pickers. These items are user interface objectives defined in Xcode. On the one hand, these objectives are the developmental tools designed by Apple to facilitate the App development. On the other hand, it also helps to guarantee the quality of App on Apple devices. Some development objectives will be described with more details in the following sections.

Generally, views after a initial login view can be divided in two categories: Administrator View and User View. With the Administrator View, the administrators of the App are able to add, delete or edit information for users and students. Administrators can also assign assessment categories to a user from the pool and export the assessment results. With the User View, the App users are able to start a new assessment session or review the past assessments. We included several screenshots of our App in this thesis to better demonstrate our user interface design. Please note that all screenshots are obtained with a iOS simulator, a tool in Xcode IDE to show the appearance of App in the portable devices during development, so, minor differences may exist between our screenshots and our App views in iPad.
After a launch View, the initial login view is activated in the App as shown in Fig. 4.3. A CCHMC logo is placed on this view, since our assessment system App is only designed for CCHMC users.

Then, a picker objective is used to choose between users and administrators as in Fig. 4.4. Picker is a standard user interface objective in Xcode for choosing from pre-defined items. From here, one can go to either one of two types of views. One is for administration, and the other one is only for an assessment session. More details will be elaborated in the next two parts, respectively.

### 4.3.1 Administrator View

In this part, we would like to describe our Administrator view design. A administrator login view in shown in Fig. 4.5. Administrators have to login the system with password. Then, App will guide administrator to administrator home view as in Fig. 4.6.

As we can see on the left part of Fig. 4.6, three major tasks- user/student management, assessment assignment, and data export- could be performed. On the right part of administrator home view, it already shows all existing users in the system. In the system configuration phase, the administrators must set up the designated users (supervising physicians), students to be assessed (resident physicians). Fig.4.7 is an example view of adding a new user in a user management view. Infant care is input as username, and contact information are also added.

As we mentioned before, the Pediatrics Milestones project defines the whole framework of assessing a resident physician. However, in a specific assessment, or for a certain group of students, only some of competencies or sub-competencies, namely the assessment
scope, may be included. In this case, the administrators must control the setting of assessment items at the beginning. We used Assessment assignment view as in Fig. 4.8 to let administrator assign assessment categories (a subset of assessment competencies, sub-competencies and corresponding Milestones) to the designated users to assess the performance of the students. In this view, we designed two buttons (green and red) to mark the selection of sub-competencies. A small flag is also used to show the selected sub-competencies.

After the assessment sessions are finished, administrator is able to login the system and export all the assessment results. Assessment results are generated automatically as a .CSV file, which can be viewed easily in the future by software such as MS Excel. Since USB or other common hardware interface are not provided on iPad, we choose to email the .CSV file to administrator email address as shown in Fig. 4.9. One example of the exported data file is shown in Fig. 4.10. The exported data could involve items such as user name, student name, assessment result score, and any other attribute the administrator would like to export.

4.3.2 User View

In this part, description of user view is provided. After user login the system, App will directly guide users to User home view. In this view, one can choose to start a new assessment session or review the past assessment results. In Fig. 4.11, an example view is shown as one starts a new assessment. Description of assessment could be added optionally for future reference. After that, students must be added in this new assessment.

Assessment configuration view is shown in Fig. 4.12 with a picker view at the
bottom. With the picker view, users could add any students from a list, which were input by administrators as in user/students management task. Please note that we also put year of students besides the names so that assessment could be performed with prior knowledge.

Fig. 4.13 illustrated the most important view of our App - Assessment view. When Assessment configuration view is finished, App will guide user to this assessment view for all assessment task. Users don’t need to leave this page until all assessment session is done. As shown in Fig. 4, this view is first divided into multiple blocks. Each block is design for one sub-competency, and description of competencies and sub-competencies are provided on the top of each block. Within the blocks, each student is listed separately, and please note that year of student is in the bracket followed the name. Also, Milestones description plus a slider tool are designed besides student’s name. A slider is one user interaction tool provide in Xcode. By using the slider, users can use the finger to move the slider in certain range. One difficulty about the Pediatric Milestone frame work is that each sub-competency involves several Milestones, and each Milestone is a paragraph to describe the progression of learning. To remind the context of each Milestone, users prefer the Milestone to be shown on the assessment view, but if we leave all the Milestone context on the screen, the Milestone will simply occupy most of screen space. To conquer this issue, we design a dynamic view with the help of slider. Both Milestone description and score next to slider bar are designed as dynamic view in our App. The effect of such design is that when users are moving sliders, Milestone and score are changing accordingly. For example, in Fig. 4.13. in first block, we have virtual student name Mike Smith in his second year. Current slider is set, so score is 43 and Milestone is shown accordingly. Note that second student is Tim Swan, and his
slider is set for score 76, then Milestone description is totally different from Mike’s. With this design, users can always move slider back and forth during the assessment to locate a proper Milestone for students, and at the same time, user interface view is not occupied by the descriptive words of Milestone.

Another issue is that users and administrators in CCHMC still want a quantitative score for the performance of resident physician. Therefore, we design a matched table between quantitative score and Milestone. Basically, we divided 1 – 100 points into several categories and each category is set to matched to certain Milestone. Table 4.1 is an example of the matching table.

We designed to make all the sub-competencies on this Assessment view, since users have the requirement which different views switch is not desirable. Therefore, to continue with more competencies assessment, users only need to slide the page upwards and the view will scroll down with more assessment items. With constrained memory of portable devices, most Apps will utilize a object reuse technique. Without exception, we also need to applied this technique since creation of a huge view is not permitted if many assessment items are assigned for assessment. In this case, the system processing behind the scene is that once users scroll down to new assessment items, some of the past user interaction objects such as sliders are released in the memory and are reused for incoming views which are about to appear.

Note the on the top right corner of Assessment view, there is one icon for saving the assessment results. Once users finished the session and press that save button, App will lead users to the view as in Fig. 4.14. This is a email selection view, listing all the
Table 4.1: Example Score Configured according to Milestones

<table>
<thead>
<tr>
<th>IDs</th>
<th>Milestones</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A13.1</td>
<td>1-20</td>
<td>Limited experience as supervisor demonstrated by difficulty stepping back from direct care</td>
</tr>
<tr>
<td>A13.2</td>
<td>21-40</td>
<td>Recognizes need to trust those being supervised but cannot accurately assess level of competency for that learner</td>
</tr>
<tr>
<td>A13.3</td>
<td>41-60</td>
<td>Can assess learners competency and align amount of supervision to learners needs but still is too hands on in direct care &amp; risks</td>
</tr>
<tr>
<td>A13.4</td>
<td>61-80</td>
<td>Accurately assess both competence and capability of learner while balancing trainee’s need for independence with patient safety</td>
</tr>
<tr>
<td>A13.5</td>
<td>81-100</td>
<td>Maximizes the balance between trainee’s professional growth and need for patient safety and adjust supervision as necessary</td>
</tr>
</tbody>
</table>

student names on it. One of goals of the Pediatric Milestone project is return descriptive meaningful assessment to students in a timely manner. So, our App is able to email the results to student right after the assessment.

As in Fig. 4.15. we also provide a email edit view in our App. Users could edit the assessment result email if necessary. Again, based on users’ opinion, we designed the evaluation result page for the email. It included student and assessment information.
A detail table is also generated automatically based on the assessment. Students could understand their current performance from description for each assessment category.

At the end, recall that in Fig. 4.16, we shown that users can start a new assessment and review the past assessment results. Fig. 4 shown a assessment review view. In this view, users are able to review the assessment results of different students. For each student, assessment categories and their Milestone are attached. A quantitative score and a average score, which is calculated based on scores of the group being assessed, are presented below the Milestone. These settings were designed to assess a student in both descriptive way and quantitative way.
Figure 4.1: Database Relationship
Figure 4.2: Hierarchical tree for user interface
Figure 4.3: Initial login view
Figure 4.4: Initial login view with picker tool
Figure 4.5: Administrator login view
Figure 4.6: Administrator home view
Figure 4.7: User/student management view
Figure 4.8: Assessment assignment view
Figure 4.9: Data export view
Figure 4.10: Exported .CSV file example
Figure 4.11: User home view
Figure 4.12: Assessment configuration view
Figure 4.13: Assessment view
Figure 4.14: Email selection view
Figure 4.15: Email edit view
Figure 4.16: Assessment review view
Chapter 5

Summary and Future Works

In this chapter, we would like to summarize our works and discuss several future possible directions.

5.1 Summary

In this thesis, we developed a assessment system based on the Pediatrics Milestone project on iPad tablet device. First, we made necessary modification to Milestone framework in the Pediatrics Milestone project based on specific requirements of APP users. And then, we implemented one pediatric residents assessment system with iPad tablet device as a assessment App. Database, user interfaces, and communication functions were all designed and implemented during our development. One APP was ready to be used on one of our demo device. The implemented assessment system is planned to be used for assessing the performance of resident physicians.

Our efforts included two major parts: 1) Modification of the Milestone framework
of the Pediatrics Milestone Project in preparation of a practical assessment system for CCHMC. Some Milestones in the Pediatrics Milestone Project need further refinement based on the requirement of individual medical education institution. Based on CCHMC users’ request, we made necessary modification on the Milestone framework; and 2) Design of user interface and database in the assessment system and implementation of the system on the iPad device from Apple Inc. App coding was performed with Xcode on Mac Pro laptop to develop a user-friendly error-proof assessment system.

5.2 Future Works

There are several future directions based on the current assessment system which could be further discussed. Here are the outline of our future works:

- **Field Test and Feedback:** Current App is only version 1.0 based on users’ requirement. Whether supervisors of resident physicians are able to use our App efficiently is unknown. Field test and feedback need to be done in the future to improve our APP.

- **Assessment data analysis for developmental progression:** After assessment data collection, time-course assessment results can be analyzed for individual resident to understand learning progression. With the knowledge of their own progression, individual students are able to plan their own improvement strategies, which is also the main objective of Milestone project. Data analysis may involve developing a quantitative presentation of the whole learning progress, and further mapping current status of students into the progress.
• **Group assessment data analysis:** Assessment results can be analyzed for multiple resident physicians with similar backgrounds. This group analysis will not only benefit individual resident, but also discover drawbacks of the educational institutions. In this way, educational institutions could have a plan to improve their teaching strategies.
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