EDUCATIONAL INNOVATION IN AN UNDERGRADUATE MEDICAL COURSE

Implementation of a Blended e-Learning, Team-Based Learning Model

by

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ABSTRACT

Medical education has been the subject of ongoing reform since the second part of the 18th century (Papa & Harasym, 1999). Most recently, medical education has been redefined to include a broad set of competencies over and above traditional expertise. In an attempt to facilitate this approach, different instructional models have been proposed. Most of these seek to foster learner engagement and active participation and promote life-long learning. Nevertheless, there is no consensus amongst medical educators about the optimal way to teach future physicians.

Despite the efforts of both researchers and local champions, instructional innovations frequently fail. Fullan (2001) ascribes this to faulty assumptions on the part of planners as well as to the inherent complexity of the organizations involved, further stating that effective change requires some degree of reculturing. This study examines the process of educational change in an undergraduate medical course over a three-year period. Formerly taught exclusively by large class lectures, the course was redesigned to include a blend of e-learning and Team-Based Learning (TBL). The process of change is described and viewed in parallel from the perspectives of both student and teacher while uncovering contextual and process elements that contributed to the outcome.
Shifting student attitudes to teaching and learning were identified over time, suggesting that these evolve in parallel to faculty experience implementing a new teaching strategy. Van Melle (2005) has suggested that acceptance of educational innovation is dependent on the environment and organizational context. The results of this study highlight the importance of these factors in the successful introduction of a new instructional paradigm as well as the value of longitudinal evaluation of instructional changes in order to better understand their transformational potential.
ACKNOWLEDGEMENTS

This has been a long journey. Long enough to have two children and to have seen several cats come and go. Long enough to plant a seed and actually watch it sprout and grow into something satisfying. But roads are lonely if you go alone, and I have been fortunate enough to have had many companions, colleagues and friends assist me along the way. My senior colleagues, Dr. Peter Brown and Dr. David Pichora suggested to me, when I was a new faculty member that “Education” was a country that I might like to visit. For that advice and for their support and that of Dr. Dale Mercer, I am grateful. Dr. David Holland was the person who introduced me to TBL and who won me over with his enthusiasm. His early support and encouragement of this project was instrumental in its success.

Dr. Lyn Shulha was one of my first teachers when I began this degree and I have been fortunate to have her as my thesis supervisor. Her cheerful and wise approach has given me direction and led me down paths I might not have taken alone. Dr. Denise Stockley and the Centre for Teaching and Learning have been co-conspirators all along. Their knowledge, advice and enthusiasm for teaching and learning have helped me grow as both a teacher and a student.
I am fortunate to be surrounded by others with a passion for to improve education. Dr. Elaine Van Melle, and her predecessor Dr. Ros Woodhouse, are both responsible for aiding, inspiring and nurturing this project. The tireless group of faculty who have worked to create, maintain, evaluate and renew the curriculum in the School of Medicine have heard and lived this story in bits and pieces and have always provided helping hands and support when the going got tough. The wizards at MedTech, Matt Simpson and Amy Allcock, have both given me amazing tools to work with and also listened patiently to my rants and ideas. Sheila Pinchin has brought knowledge and experience from the world of “real” teaching and is an endless source of encouragement.

I’m grateful to Heather Conway for helping me enter, collate and organize the huge amount of data generated over the past three years. Thank you also to King Luu who lent his time, statistical expertise and advice as I worked to make sense of it all in the past few months.

Most importantly, I’d like to thank my family. Evelyn and Douglas, my parents, you taught me to work hard but you also taught me the importance of a loving home. Andrew, James and Eileen, I’ve stolen many hours away from you in the basement, plotting, conducting, analyzing, writing and re-writing this thesis. The three of you are my roots, and my anchor, and my heart.
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CHAPTER ONE: INTRODUCTION

Background

The last century has seen an unprecedented amount of change in both medicine and medical education (Cooke, Irby, Sullivan, & Ludmerer, 2006). In addition to an explosion in medical knowledge and technology, the healthcare environment has become influenced by “patient consumerism, government regulations, financial imperatives, medical information on the internet, [and] litigation” (Frank, 2004, p.27) as well as by changes in physicians’ work expectations and the emergence of new types of healthcare delivery (Dent, & Harden, 2005). In response to these changes, regulatory groups such as the Royal College of Physicians and Surgeons of Canada (RCPSC) and the Canadian College of Family Practice (CCFP) have developed frameworks that make explicit a set of competencies required for the modern physician. For example, in Canada, the RCPSC has articulated six physician roles, in addition to that of medical expert, that underlie the assessment of postgraduate specialist medical trainees (Frank, 2004).

Medical schools are now mandated by accrediting bodies to teach their graduates a broad skill set including communication skills, the medical consequences of common societal problems, an understanding of diversity, medical ethics, and human values (Liaison Committee on Medical Education, 2005). Information literacy (Murphy,
Ingram, & Howard, 1998) practice management, and problem solving skills (General Medical Council, 2003) are also regarded as essential to the training of future physicians. Driven partly by these new standards and partly by of conceptions of cognition and learning (Shuell, 1986), the delivery of undergraduate medical education has also undergone a transformation in the past three decades.

Medical Education in the Last 100 Years

Curricular change is a recurring theme in medical education. Papa and Harasym (1999) describe five curricular models that have emerged in North American medical education since the late 17th century: (1) apprenticeship, (2) those based on disciplines, (3) organ-systems, (4) clinical problems, and most recently, (5) clinical presentations (Woloschuk, Harasym, Mandin, & Jones, 2000). Medical education has undergone significant changes since the publication of Abraham Flexner’s report in 1910. Flexner, an educator, was hired by the Carnegie Foundation for the Advancement of Teaching to study and make recommendations about the education of physicians in North America, addressing concerns that medical education of the day lacked both standardization and rigour (Beck, 2004). The reforms that followed led to the regulation and standardization of medical education in North America with a redefinition of the curriculum to consist of two years of laboratory sciences followed by two years of hospital-based clinical
rotations. Flexner’s work was instrumental in developing standards for medical education, which had previously been lacking. The Flexnerian model emphasized the scientific basis of medicine over the haphazard clinical apprenticeship model that had dominated previously. It was rapidly adopted and dominated North American medical education for much of the 20th century.

Since the 1990s, many medical schools have redesigned their curricula to encourage the development of active, self-directed and life-long learning strategies in students (Kelly, Haidet, Schneider, Searle, Seidel, & Richards, 2005). Problem-based learning (PBL), which was pioneered at McMaster University (Schmidt, 1983), is an instructional technique that has been widely adopted for this purpose. During PBL, students learn in small groups by exploring fictional cases that are constructed to simulate real patient situations. These integrate basic and clinical sciences and require students to identify social, psychological, and ethical issues that intersect with the medical conditions being studied. Ideally, students develop learning objectives, research, collaborate and interact with each other as they negotiate each case from start to finish.

Although there are exceptions, most PBL groups include a facilitator who may be an expert or non-expert faculty member or even a senior student. This raises a major problem that has dogged the implementation of PBL: because of the low student-
facilitator ratio required for this technique (generally one facilitator for every 6-12 students), human resources can be a limiting factor.

Medical School Curricular Structure

The School of Medicine (SoM) described in this research offers a four-year program leading to a doctor of medicine (MD) degree. The average student entering the medical program has over four years of prior experience as a university student; some enter after graduate degrees. Students are not required to adopt a particular course of study prior to acceptance into medical school; therefore, the students come from a variety of academic disciplines, bringing with them a heterogeneity of knowledge and experience.

Until the early 1990s, the curriculum reflected Flexner’s original recommendations. Instruction in the pre-clinical years consisted largely of didactic, teacher-focused instruction. The curriculum was revised in the early 1990s, in part due to changing standards set by the Liaison Committee on Medical Education (LCME, the North American accrediting authority for institutions granting the M.D. degree). Departmental courses were combined and reformatted to create courses based on body organ systems. Weekly, small-group clinical skills and PBL sessions were introduced into the pre-clinical curriculum. Horizontal courses were created and interwoven
throughout the three pre-clinical years, emphasizing clinical skills and the role(s) of the physician within society.

The curriculum is currently divided into three main sections, which are termed “Phases”. Phase I is a 4-month block in which students are taught a wide variety of basic scientific facts and concepts foundational to the study and practice of clinical medicine. In Phase II, students are introduced to the normal and abnormal functioning of the body, with the teaching units organized by organ system (for example: cardiovascular, musculoskeletal, and renal). Phase II begins in January of first year and continues until December of third year. This portion of the curriculum is divided into three instructional blocks and one independent research component.

PBL is introduced in Phase II with weekly small-group meetings. Phases I and II together comprise the pre-clinical component of the MD program. Phase III is the clinical component of the students’ training. The student participates in a supervised fashion in the assessment, management and follow-up of patients in a variety of venues including physicians’ offices, hospital clinics, in-patient wards, emergency rooms and community settings. Students are expected to be able to function as a member of a clinical team including physicians, nurses and other health care professionals.
The curricular reform initiated in the early 1990s has been effective in temporally linking related basic and clinical science content using a systems-based approach; however, fostering learner engagement and active participation has proven to be an ongoing challenge. Both clinical skills and PBL courses require a significant number of small group facilitators. There is perennial difficulty recruiting and retaining an adequate number of faculty members to meet the needs of both courses. Increasing enrollment (30%) over the past 5 years has compounded this problem.

Despite longstanding concerns in the educational literature about the utility of the lecture (Hurst, 2004), most of the SoM’s pre-clinical curricular content continues to be delivered using large-class didactic methods. With the exception of clinical skills and the research component, the objectives of all of the courses in each of the pre-clinical instructional blocks are examined by a combination of multiple-choice and short answer examinations administered at the end of each block. Students discover early on in their course of study that the bulk of the exams require the recall of lecture material. This causes many students to focus on knowledge components (the so-called “medical expert” competency) at the expense of the content and competencies emphasized during non-didactic teaching sessions.
The Research Setting

Currently taught in the winter term of the first medical year, the musculoskeletal (MSK) course spans a 4-week period within a 19-week term. The course involves collaboration between faculty from the Departments of Medicine (Rheumatology and Infectious Disease), Pathology, Pharmacology, Physical Medicine and Rehabilitation, Radiology, and Surgery (Orthopaedic and Plastic Surgery). Up to 25 faculty members have historically been involved in the delivery of classroom lectures, often leading to poor coordination of the material presented to students.

Since taking on the role of musculoskeletal course director, I have used technology to enhance the course. While I initially used the University’s learning management system (WebCT © Blackboard Inc) to distribute electronic versions of lectures, over time, additional instructional possibilities became available. Early experience in the use of technology, combined with a growing personal interest in active learning techniques, has developed into a new instructional format for the course. Since 2005, a blended instructional design has emerged using a combination of self-directed e-learning and classroom team-based learning (TBL). Authentic clinical cases are used as the basis for much of the course content, in both virtual and face-to-face settings. The
process of change has been emergent and iterative, guided by student feedback and informed by educational literature.

Research Questions

The purpose of this research was to develop a better understanding of the implementation of a non-traditional instructional model over a 3-year period. The larger goal is to inform those who may be considering the introduction of similar initiatives in other courses and programs of study. To fulfill this purpose I address three specific questions:

1. What was the evolution in the design and implementation of the musculoskeletal (MSK) course between 2005 and 2007?
2. How did each cohort of students respond as the course design evolved over time?
3. What were the critical elements that influenced (both positively and negatively) the course outcome in each iteration?

Organization of Thesis

This chapter has set the stage by situating the work within the larger context of medical education as it has evolved over the past century. The local context has been outlined, and three research questions have been articulated to frame the subsequent methodology, analysis and discussion.
Chapter Two consists of a review of the literature pertaining to key topics and themes that explore the rationale underlying this instructional change. Chapter Three outlines the methodologies involved in each stage of the research, from data collection to analysis. Findings are presented in Chapters Four and Five, organized by each of the three research questions.

In Chapter Four, both quantitative and qualitative data are used to answer the original queries. This is followed by a reflective narrative (Chapter Five) detailing my early experience as a faculty member in the School of Medicine, told from the perspectives of a former medical student and developing teacher. The factors that motivated me to explore new forms of instruction are described along with significant milestones along the road to curricular change. These findings and analysis are discussed in Chapter Six; linkages are made to the literature presented previously as well as that related to complexity and change. Key elements that influenced this instructional innovation are outlined. Future research directions are considered.
CHAPTER TWO: LITERATURE REVIEW

Overview of Chapter

The chapter begins with a consideration of the process by which university professors learn to become teachers. A case is made for the consideration of active learning in the design of instruction. TBL is described with particular reference to implementation in the field of medical education. Blended learning is defined and best practices are outlined.

Learning to Teach in the Ivory Tower

Harpaz outlines four pictures that represent a traditional conceptualization of schooling where “learning is listening; teaching is telling; knowledge is an object; and to be educated is to know valuable content” (2005, p. 137). This model of learning continues to inform instructional practices and curricular design at many medical schools (Newman, 2002) and is intuitively accepted by many students, teachers, and decision makers. When students are taught using traditional didactic methods, poor information transfer and knowledge retention have been documented. Wieman (2007) suggests that this may be related to the limitations in human short-term memory that have been identified by cognitive psychologists, further noting that when teaching includes more engaging methods, students’ achieve a better understanding of fundamental concepts.

While newer theories of learning have been used to inform medical educational
planning, the deeply embedded pictures of traditional learning have proven difficult to change amongst front-line teachers and learners. After reviewing North American medical curriculum reform since 1765, Papa and Harasym (1999) stated, “medical educators must call upon and utilize the literature, research methods, and theoretical perspectives of cognitive science if future curricular reform efforts are to move forward efficiently and effectively.” (p. 154).

It is unfortunately the norm that fledgling professors lack specific training and expertise as teachers. “Doctoral students who intend to become teacher-scholars typically have little opportunity for systematic professional development as teachers; many complete their doctoral studies without ever having taught a class, taken an education course, or had any sort of organized opportunity to develop their teaching skills” (Trautmann, 2008, p. 42). Austin, Sorcinelli and McDaniel have identified that “teaching is a primary source of anxiety among new professors, many of who begin their first academic positions with little or no preparation in teaching” (2007, p. 65).

New faculty members are generally hired for their content expertise and research skills rather than their instructional repertoire; the former has been equated with competence in the latter (McKeachie, 2007). Traditional transmissive instructional methods (lectures and laboratories) have been used for generations and the presumption
is that new teachers will emulate what they themselves have experienced as students.

However, Trautmann (2008) suggests that these conventions are being broken down by an improved understanding of how individuals learn as well as by an increasing diversity of students and the emergence of educational technologies that facilitate less traditional paradigms of learning.

Kugel (1993) has outlined five stages, which describe the development of a professor as teacher (see Table 1). Early on, higher education teachers are concerned with their own performance. As they gain confidence in the classroom, focus shifts to the development of improved subject matter content. Dissatisfaction with student learning prompts some to recognize the diversity of student learning approaches and other qualities and causes them to adopt new educational techniques. While this may accommodate a wider audience, the emphasis is still on teacher performance rather than student engagement. A modern image of learning shifts focus away from the teacher and centres instead on the learner. Kugel’s final two stages of teacher development recognize the student as an active participant, aspiring toward the goal of educational independence. The effective teacher, by this standard, is successful when she has been rendered unnecessary.
Ten Cate, Snell, Mann, & Vermunt (2004) have described a two-part model that can be used to reflect upon and plan teaching. These authors promote evaluation of the amount of guidance that students require in each educational setting, reconceptualizing the teacher’s role as providing just enough direction to promote the development of “constructive friction between learning and teaching” (p. 221). This implies a paradigm shift where the teacher’s role is to balance external guidance carefully with student self-regulation, providing just enough structure within the learning experience to enable the student to actively participate in the acquisition of new knowledge and skills appropriate for their developmental level.

This type of participatory or active learning employs “a variety of cognitive processes and verbal and nonverbal learner behaviours” (Kelly et al, 2005, p.112). Talking, listening, writing, reading and reflecting occur simultaneously and synergistically to increase assimilation and retention of knowledge. In addition to the specific instructional elements listed previously, active learning also involves the use of specific learning strategies and teaching resources that set the stage for student engagement (Meyers & Jones, 1993).

Teachers bring a variety of personal experiences and biases that may shape their approach. Five teaching perspectives have been suggested: information transmission,
Table 1. The five ages of a lecturer  
adapted from Kugel (1993)

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<th>Focus</th>
<th>Characteristics</th>
<th>Transitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Self</td>
<td>Teacher concerned with own survival in the classroom.</td>
<td>Once survival assured, focus shifts to subject matter.</td>
</tr>
<tr>
<td>2</td>
<td>Subject</td>
<td>Teacher enthusiastic; works to extend own knowledge and share with students.</td>
<td>Beginning of awareness that student learning may not be optimal.</td>
</tr>
<tr>
<td>3</td>
<td>Student</td>
<td>Teacher becomes aware of heterogeneity of students – adopts a wider variety of instructional approaches.</td>
<td>Teacher begins to understand the limits of focusing only on teaching approaches.</td>
</tr>
<tr>
<td>4</td>
<td>Student learning</td>
<td>Teacher introduces student activities and opportunities for learning.</td>
<td>As students engage with their work their level of responsibility also increases.</td>
</tr>
<tr>
<td>5</td>
<td>Student as an independent learner</td>
<td>End point: the student knows how to learn for him/herself.</td>
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apprenticeship, development, nurturing, and social reform (Pratt, Collins, Selinger, 2001). The related Teaching Perspectives Inventory (TPI) allows teachers to articulate their beliefs, values and assumptions about teaching using this model. This can serve to aid reflection and the study of instructional strategies.

There is a call for teachers of adults to be critically reflective in their practice of teaching. For several years now professions have pushed for their members to reflect critically on the underlying assumptions and values that give direction and justification to their work. For many teachers this is not an easy task. What is it that one should reflect upon? How are the underlying values and assumptions to be identified? In other words, the objects of critical reflection are not self-evident. Indeed, it is something of a new twist to look not only at the world, but at the very lenses through which we view the world (Pratt, et al., 2001. p. 8.)

Team-based Learning

Originally described by Dr. Larry Michaelsen, a professor of business at the University of Oklahoma, TBL has been described as “a set of instructional principles designed to foster the effectiveness of small groups working independently in large classes with high learner:faculty ratios” (Kelly et al., 2005, p. 113). Many authors have recogized that learning is an intrinsically social activity (Bruner, 1966; Chickering & Gamson, 1987). When students work together in small groups, they are required to communicate with and learn from each other, becoming actively engaged with the material while being exposed to perspectives other than their own and as a result learning more effectively (Fink, 2004; National Leadership Council, 2007). Rather than being
simply an adjunct to an existing lecture-based course, TBL is a specific teaching strategy. It requires a fundamental shift in course structure by making small group activities the primary classroom focus (Fink, 2004).

An essential element of this method is the transformation of student groups into so-called high performance learning teams; this is achieved by careful design of learning activities and assessment strategies to promote collaboration and accountability.

When the groups are properly formed, remain intact long enough to become cohesive teams, and are repeatedly given challenging tasks with prompt and clear feedback, then students learn the content, they learn how to use the content, they learn about themselves and about how to interact with others on major tasks, and they learn how to keep on learning after the course is over.” (Fink, 2004, p. 8).

This has particular appeal to medical educators seeking to embed the development of essential competencies such as communication, collaboration, management and professionalism into their instructional design.

TBL combines individual out-of-class preparation with in-class assessment and group application exercises. Inter- and intra-group peer discussion is integral to the learning that occurs. In medical school courses, classroom exercises usually take the form of patient cases. There is a long tradition of case-based learning in medicine: postgraduate medical training is built around the care of real patients both informally (as part of clinical care) and formally (as “teaching rounds” sessions). The last 20 years have
seen a surge of interest in the inclusion of simulated case-based learning in undergraduate medical education. In addition to promoting motivation, learning activities designed around case-studies “promote independent study directed toward issues that would constitute a realistic discussion in medicine” (Shanley, 2007, p. 483).

As they unravel, inquire about and make sense of case-based problems, students are ideally engaged both emotionally and cognitively with the course content. This engagement is intended to promote the processing and integration of ideas, creating linkages with prior knowledge and facilitating subsequent use of course content and concepts (Knapper, 2007) and, ideally, elaboration. Elaboration is a term used to describe a type of knowledge organization that has been observed in successful diagnosticians. These individuals have successfully organized their knowledge into networks of relationship in memory and are able to relate these to novel problems, which facilitates reasoning (Bordage, 1994).

Blended Learning

Blended learning has been defined as the combination of face-to-face and electronic learning opportunities while reducing classroom contact hours (Dziuban, Hartman, Moskal, 2004). “Electronic learning or more commonly, e-learning is an all-encompassing term to describe learning supported by the use of information and
communications technology” (Academy of Medical Royal Colleges, 2007, p. 5). This may take a variety of forms ranging from electronic posting of course materials to more interactive models using self-directed modules, formative assessment, email, discussion boards, wikis and other collaborative tools. The common theme is one of engagement, with students using online resources to interact with course content and gauge their knowledge and progress (Twigg, 2003). An important distinction is made between blended learning and Web-enhanced courses that do not reduce classroom time. Inherent in blended learning is a fundamental redesign of the instructional model, shifting from lecture to student-centred instruction, increasing all forms of interaction and incorporating formative and summative assessment (Twigg, 2003; Dziuban et al, 2004).

The Learning Technology Consortium Study examined the effect of the introduction of Web-enhanced teaching in 7 universities in the United States (Wingard, 2001). Faculty goals for Web enhancements were categorized as either pragmatic or instructional; it was noted that these two categories were not necessarily mutually exclusive. Many faculty members reported changing goals over time “towards increased awareness of instructional benefits” (p. 30). In many studies, the implementation of a blended course was coexistent with a pedagogical redesign (active vs. passive learning) and it is not always clear how to separate this out from the overall intervention (Riffell &
Sibley, 2003). Graham, Cagiltay, Lim, Craner, & Duffy, (2001) used Chickering and Gamson’s (1987) “Seven Principles for Good Practice in Undergraduate Education” to evaluate four online university courses. Their observations, which are summarized in Table 2, provide a framework that can be used to evaluate other online courses and modules.

In a recent review of the effective use of educational technology in medical education, the AAMC Institute for Improving Medical Education highlighted the concept “that use of technology be linked to what we know about learning” (2007). Harden (2008), endorses this, commenting that “too often our students are subjected, in the guise of e-learning, to an amateurish forrago that is neither an inspiring or rewarding learning experience”.

The importance of attention to pedagogical principles and instructional design as technology is supported by the results of the Pew Charitable Foundation Program in Course Redesign (Twigg, 2003). Thirty institutions across the United States received funding to support the redesign of existing college and university courses to include technological tools. All of the institutions studied were able to reduce cost significantly by implementing technologically enhanced instruction. Student satisfaction with instructional methods and attitudes towards course content were improved, as were
course-completion rates. While different models of instruction were adopted at each school, six common characteristics were identified across all of the redesign projects. These included a significant increase in active and learner-centred activities that were facilitated by technology.

Allen, Walls & Reilly (2008) describe the successful implementation of a blended learning design (online modules combined with didactic lectures) in an undergraduate medical anatomy course; however, these authors noted both opportunities and pitfalls with the introduction of online modules. Motteram (2006) identified that teachers must consider the time available for students to complete out-of-class online tasks when designing a blended curriculum, noting that “if tasks are relevant and are set up well, then they can help learners develop their knowledge and skills” (p. 29).

Combining face-to-face learning opportunities, especially those that encourage a dynamic interplay between learner and teacher, with e-learning may help to obviate some of the potential pitfalls of purely online instruction (Academy of Royal Medical Colleges, 2007).
### Table 2. Seven Principles for Effective Online Teaching
Adapted from Graham, Cagiltay, Lim, Craner, & Duffy, (2001).

<table>
<thead>
<tr>
<th>Chickering and Gamson’s Principles</th>
<th>Implications for online courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Good practice encourages student-faculty contact</td>
<td>Instructors should provide clear guidelines for interaction with students.</td>
</tr>
<tr>
<td>2) Good practice encourages cooperation among students</td>
<td>Well-designed discussion assignments facilitate meaningful cooperation among students.</td>
</tr>
<tr>
<td>3) Good practice encourages active learning</td>
<td>Students should present course projects. This may be done asynchronously.</td>
</tr>
<tr>
<td>4) Good practice gives prompt feedback</td>
<td>Instructors need to provide two types of feedback: information feedback and acknowledgment feedback. Peer feedback (to asynchronously posted projects, as in #3) can be used to enhance learning.</td>
</tr>
<tr>
<td>5) Good practice emphasizes time on task</td>
<td>Online courses need deadlines.</td>
</tr>
<tr>
<td>6) Good practice communicates high expectations</td>
<td>Challenging tasks, sample cases, and praise for quality work communicate high expectations.</td>
</tr>
<tr>
<td>7) Good practice respects diverse talents and ways of learning</td>
<td>Allowing students to choose project topics incorporates diverse views into online courses.</td>
</tr>
</tbody>
</table>
CHAPTER THREE: METHODS OF DATA COLLECTION AND ANALYSIS

Overview of the Chapter

This chapter begins by restating the three research questions. For each question, the methods of data collection are outlined followed by a summary of analytic methods applied to the data. These are referenced back to the research questions and summarized in Table 3.

Research Questions

As outlined in chapter 1, the purpose of this research is to develop a better understanding of the implementation of a blended e-learning TBL instructional model in an undergraduate medical course over a 3-year period. The larger goal is to inform those who may be considering similar changes in their own instruction. To fulfill this purpose I have collected data around three specific questions:

1. What was the evolution in the design and implementation of the musculoskeletal (MSK) course between 2005 and 2007?

2. How did each cohort of students respond as the course design evolved over time?

3. What were the critical elements that influenced (both positively and negatively) the course outcome in each iteration?
Table 3. Methods of Data Collection and Analysis

<table>
<thead>
<tr>
<th>Question</th>
<th>Method of data collection</th>
<th>Source of data</th>
<th>Data to be collected</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>What was the evolution in the design and implementation of the musculoskeletal (MSK) course between 2005 and 2007?</td>
<td>Document review</td>
<td>Course schedules, Syllabi, Administrative emails (staff/faculty), MSK course reports</td>
<td>Structure of course as delivered in 2005, 2006 and 2007</td>
<td>Development of course description and chronology, Identification of significant changes over time</td>
</tr>
<tr>
<td>How did each cohort of students respond as the course design evolved over time?</td>
<td>Document review, Student research questionnaire</td>
<td>Historical course evaluation data (2005 and 2007), All students enrolled in MSK course in 2005, 2006 and 2007</td>
<td>Student attitudes towards instructional methods, Student ratings of course effectiveness and suitability of curricular elements</td>
<td>Descriptive statistics and graphs (SPSS and excel) characterizes the responses of each cohort of students, ANOVA (SPSS) compares the responses between cohorts and identify any significant differences</td>
</tr>
<tr>
<td>What were the critical elements that influenced (both positively and negatively) the course outcome in each iteration.</td>
<td>Document review, Student research questionnaire, Autobiographical narrative</td>
<td>Historical course evaluation narrative data (2005, 2006, 2007), All students enrolled in MSK course in 2005, 2006 and 2007</td>
<td>Major themes that influence student opinion of each iteration of the course (course evaluation data and research questionnaire), Major themes identified by the course director in each iteration of the course (autobiographical narrative)</td>
<td>Grounded theoretical approach (Atlas.ti) used to identify themes expressed by both students and the course director</td>
</tr>
</tbody>
</table>
Methods of Data Collection

Question #1

The first question was addressed by reviewing documents relevant to the MSK course. During the study period relevant documents were identified and catalogued chronologically and by type (Appendix A). These included course schedules, syllabi, reports, emails relating to administrative matters and other administrative documents. These documents were used to develop a picture of the evolution of the course design during the study period, highlighting significant changes in both the course and the context within which it was implemented.

Question #2

This question was addressed using a combination of historical and original data generated for this study.

Historical course evaluation data

Course evaluation processes are variable within the School of Medicine. While many course directors rely on a standard set of questions administered by the Undergraduate Medical Education office, others have designed evaluation processes specific to their own courses. The musculoskeletal course is evaluated annually on the last day of the course using a customized student survey. Completion of the survey is
voluntary and anonymous. Results are collated and circulated back to the course teachers as well as to educational administrators within the School of Medicine. Use of these data for this study was approved by the Health Sciences Research Ethics Board (REB).

The majority of survey items are drawn from the standardized University Survey of Student Assessment of Teaching selection list (available at the institution used in this study); however, the survey is modified annually as specific issues are identified from previous surveys. For example, only 25% of students surveyed in 2005 identified that the course web page was helpful and informative. Therefore, in 2006, four more specific items were used to explore the theme of website utility (“The course website was easy to navigate”; “The course website modules helped me to learn and better understand the course material”; “Web-based quizzes and interactive cases helped me to learn and better understand the course material”; “The online references linked to from the course website were helpful and informative”).

Survey items were completed using a standard 5-point Likert scale (McMillan & Schumacher, 1997) ranging from 1: Strongly Disagree to 5: Strongly Agree. The MSK survey does not include questions designed to evaluate specific faculty members; however students may include narrative comments, which sometimes identify faculty names. Any comments naming specific teachers have been removed from analysis in
order to preserve the privacy of individual faculty members. Survey items used between 2005 and 2007 are tabulated in Appendix B.

Student Research Questionnaire

For the purpose of this research, a three-part questionnaire was developed to investigate student conceptions of different instructional methods: TBL, online learning and lectures (Appendix C). The Health Sciences Research Ethics Board (REB) approved the survey and research protocol. The survey was administered during the last 10 minutes of a MSK review session held in late April, just prior to the end-of-term examination period. An information letter explaining the research project was circulated electronically to the students prior to the review session. Completion of the survey was voluntary and anonymous.

The first part of the survey included 21 items concerning attitudes towards working with peers, the value of working in groups, online study and lectures. Respondents were also asked to self-rate their mastery of the six global course objectives. Items that explored attitudes towards different instructional models were analyzed separately from those related to objectives. Each item was scored using a 5-point Likert scale ranging from 1: Strongly Disagree to 5: Strongly Agree.
Nine of the survey items were taken from the Value of Teams Survey, which has been used previously to evaluate student attitudes towards TBL (Levine, O’Boyle, Haidet, Lynn, Stone, & Wolf, 2004). The original Value of Teams Survey consists of 13 items, 9 of which purport to measure two dimensions, working with peers (4 items) and the value of group work (5 items). Eight of these items were included in the current study’s survey. Omitted were the one negatively phrased item (“It is a waste of my time to work in groups”) and three of the original survey’s distracters. While these items were no doubt essential in enabling the authors to establish arguments for the instrument’s reliability and validity, a decision was made not to include them in this student research questionnaire based on the need to keep the survey a reasonable length.

Additional Likert-scale items were developed by this author to investigate student attitudes towards online study and lectures. These were constructed to mirror the phrasing of the group work questions (“an effective way to learn” and “an effective way to practice what I have learned”). Because of informal student comments regarding their preference for the efficiency of lectures, another two questions were added exploring perceptions of efficiency in lecture-based and online learning.

The second part of the survey listed 11 items representing a set of idealized educational objectives for the course from my perspective as teacher. These described
features of the instructional experience from the student point of view (“allows me control of my learning”, “allows me to apply what I’m learning”, “helps me integrate my learning”, “helps me judge the extent of my own learning”) as well as desired outcomes or products of the experience (“a practitioner’s perspective”, “brings medicine to life”, “helps me to become more reflective”, “strengthens my communication skills”).

This list was developed largely based upon my experiences and evolution as a medical teacher; however, it was also informed by the needs expressed by students in formal and informal course evaluation feedback over the years (“organizes a large amount of material”, “guides me through difficult topics”). For each objective, students were asked to rank the three instructional methods included in the course in terms of their suitability to achieve the stated goal (from 1=most suited to 3=least suited).

**Question #3**

The historical course evaluation data provided insight into the effects of course innovation as experienced by the students as well as their perceptions of the teaching and learning activities included in the course. As such, these data contribute to answering the third research question. In addition, the final part of the student research survey included two open-ended questions. Students were asked to complete statements describing the most useful features of online study and TBL from their perspective. While there are
drawbacks to relying exclusively on student feedback data as the only method of evaluation of teaching, “students are uniquely placed to provide feedback on education delivery and the overall education experience - after all, they are at the point of use and are essentially the customer base. They are in the ideal position to evaluate learning and teaching and provide constructive opinion” (Quality Assurance Agency for Higher Education).

In considering the transformation of the MSK course, it is important to include the teacher’s voice, which in this case is autobiographical. Given that the results of the study may inform other instructors who may be considering the adoption of e-learning and TBL, an exploration of my own motivations, experiences, and reactions over time provides a context within which to interpret the findings that are described. To this end, a narrative is included in Chapter Five, intertwined with the other more traditional elements of this thesis.

Methods of Data Analysis

Multiple methods of analysis were used because of the variety of the data. The initial document review allowed the development of a chronology of changes in course structure. Course evaluation data from the study period was analyzed using SPSS a statistical software package. Eight questions were common to all 3 years of course
surveys (Table 4). Descriptive statistics for these items were tabulated by year to identify
positive or negatives trends in student opinion. These were compared using an analysis
of variance order to identify any significant differences between the groups.

Research survey items for all 3 years relating to student impressions of different
instructional methods (group work, online learning and lectures) as well as their self-
perceptions of mastery of the course objectives were also analyzed using SPSS.
Descriptive statistics for each question were stratified by year, as with the course survey,
to identify trends. Survey items were designed to be grouped into three dimensions
(similar to the Baylor Value of Teams survey), each reflecting student attitudes towards
different instructional techniques. The validity of these groupings was explored using a
principal component analysis, which is described in detail in Chapter Four.

Student rankings of the suitability of each instructional method in achieving each
of the 11 educational objectives were tabulated and graphed using Excel software. Some
students only recorded their highest or lowest ranking for individual objectives; therefore
only complete datasets (where a ranking was attached to all three instructional methods)
were analyzed. While this approach necessitated the exclusion of some datasets (and
Table 4. Common Course Evaluation Survey Items from 2005 and 2007

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Overall this is an excellent course</td>
</tr>
<tr>
<td>2.</td>
<td>I learned a great deal from this course</td>
</tr>
<tr>
<td>3.</td>
<td>The course was helpful in developing new skills</td>
</tr>
<tr>
<td>4.</td>
<td>I felt that this course challenged me intellectually</td>
</tr>
<tr>
<td>5.</td>
<td>My interest has been stimulated by this course</td>
</tr>
<tr>
<td>6.</td>
<td>The course covered the right amount of material</td>
</tr>
<tr>
<td>7.</td>
<td>The workload in this course was reasonable and appropriate</td>
</tr>
<tr>
<td>8.</td>
<td>The course material was presented at a satisfactory level of difficulty</td>
</tr>
</tbody>
</table>

risks skewing the data), it was felt to be justified as the majority of responses were complete.

Graphs were developed for each educational objective, stratified by year (Appendix D). These outlined the number of students who had ranked each educational technique from 1 (most appropriate) to 3 (least appropriate). Changes in the rank order of the different methods were compared over time to identify evolving student perceptions of teaching and learning.

Narrative comments from both the course evaluation and student research surveys were coded to reflect the survey (CES or SR), the year (05, 06, or 07) and the individual (a non-identifying number used to differentiate answers from different students). These were analyzed using a grounded theory methodology (Patton, 1990).

The comments were coded and grouped, uncovering themes emergent from the
data. Data from each cohort of students were analyzed separately, identifying trends over time. Finally, my experiences as a teacher were outlined in narrative form utilizing a reflective approach as advocated by Richardson, who noted that “experiences are connected to other experiences and are evaluated in relation to the larger whole” (1997, p. 30).
CHAPTER FOUR: RESULTS

Overview of the Chapter

The chapter begins with a description of student demographics during the study period. Using data identified from the document review, a picture emerges of the changing shape of the course over the 3 years, providing an answer to the first research question.

The second research question is addressed by comparing the attitudes and stated preferences of each cohort of students, using data from historical course evaluations as well as that from the student research survey. The latter is analyzed in three parts: attitudes towards different instructional modalities, self-perception of mastery of course objectives and student perceptions of the advantages of TBL and e-learning. Shifts in student attitudes over time are identified.

Narrative data from both students and teacher (Chapter Five) are presented to help unravel the third research question. These data are used to uncover facilitators and detractors that contributed to the shape and pattern of educational change in the MSK course between 2005 and 2007.
Demographics

Student enrollment, sex breakdown, and province of origin are summarized in Table 5. The composition of each of the three classes was similar other than an increase in the proportion of females over time (see Table 5). One of the students enrolled in the course in the first year was originally a member of the previous class who returned following a leave of absence. (This student is not included in Table 5).

Table 5. Student Demographics

<table>
<thead>
<tr>
<th>Research study year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class size</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Male:Female</td>
<td>52:48</td>
<td>45:55</td>
<td>46:54</td>
</tr>
<tr>
<td>Province of origin:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ontario</td>
<td>76</td>
<td>70</td>
<td>78</td>
</tr>
<tr>
<td>Alberta/BC</td>
<td>14</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>Quebec</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Other/USA</td>
<td>8</td>
<td>8</td>
<td>5</td>
</tr>
</tbody>
</table>

Question #1

Introduction to Course

An hour-long introductory session was held on the first day of the course in all 3 years (Table 6). In all years, standard items such as course objectives and evaluation structure were outlined. In the second and third years there was increased emphasis on an explanation of the instructional format. Students completed a sample readiness
assessment test based upon a short reading available in class to illustrate this component of TBL. In 2006 and 2007, a tour of the course website was included outlining expected preparation and evaluation milestones. In the third year, student teams were created during this introductory session by having students line up and sort themselves based on teacher-determined criteria.

*Changes in Course Content over Time*

While the bulk of the course content was relatively stable over time, in the third year, there was one significant change. In 2005 and 2006, several sessions were devoted to teaching ‘Pain’ topics relevant to the MSK system. This was done collaboratively with teachers from the Palliative care course that is taught in parallel to the MSK course. In 2007, all of the Pain teaching was consolidated within the Palliative care course, resulting in a reduction of MSK course instructional time by 480 minutes in comparison to the previous year. It should be noted that these differences are largely a form of curricular bookkeeping, important to the administrators of the undergraduate program. From the student point of view, the curriculum is seen as a whole; therefore, this change was largely invisible to the learners involved.
**Classroom Time Weightings by Instructional Method**

Total classroom time scheduled appears to decrease over the study period; however, if the analysis is done eliminating ‘Pain’ teaching in the first 2 years, there is little change in total classroom time for each year. In all years, didactic methods predominated; however, over the period of the study there was an increase in both the absolute and the relative amount of time scheduled for TBL and a parallel reduction of time scheduled for didactic teaching (Table 7). The differences between 2005 and 2007 are less pronounced if the Pain sessions are removed from analysis (Table 8); however, even with this adjustment, there is a 15% reduction in didactic teaching over this period.

**Table 6. Content of Introductory Sessions**

<table>
<thead>
<tr>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course aims</td>
<td>Course aims</td>
<td>Course aims</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Evaluation</td>
<td>Evaluation</td>
</tr>
<tr>
<td>Personal and global relevance</td>
<td>Overview of content</td>
<td>Overview of content</td>
</tr>
<tr>
<td>Team activities</td>
<td>Linkages to Phases I and III</td>
<td>Linkage to Phase I and III</td>
</tr>
<tr>
<td></td>
<td>Description TBL</td>
<td>Group formation</td>
</tr>
<tr>
<td></td>
<td>Sample RAT (Global relevance)</td>
<td>Description TBL</td>
</tr>
<tr>
<td></td>
<td>Website tour</td>
<td>Sample RAT (Global relevance)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Website tour</td>
</tr>
</tbody>
</table>
Physical Space

In the first year of the study, all whole-class sessions (lecture and TBL) were scheduled into a fixed seating, tiered auditorium in the basement. This auditorium, which seats 107, is used for most of the teaching in Phase IIA and had been booked 12 months in advance, consistent with the University’s usual booking practices. In the second year, most of the TBL sessions were relocated to a former hospital gymnasium. Digital projection and amplification equipment was brought in for each session in the gymnasium. During these sessions students were seated at round tables to facilitate team activities. Some lecture sessions were also scheduled in the gym in order to minimize student travel between classes. One TBL session was re-located to a larger auditorium because of double-booking which prevented use of the gym.

During the third year, all of the lecture sessions were scheduled in the fixed auditorium. Student feedback from the previous year indicated that space suitable for TBL was suboptimal for lectures. At the suggestion of one of the Meds 2009 students, a large classroom (and sometimes research lab) on the top floor of one of the engineering buildings was booked for most of the TBL sessions. This room was equipped with reconfigurable tables and chairs with a capacity of approximately 100. As with the gymnasium, digital projection equipment was not available. Two other smaller teaching
spaces were used for TBL in the third year. Because these rooms did not accommodate the entire class, these TBL sessions were repeated more than once.

Course Website

The course website was redeveloped each year of the study as new information technology resources became available. The technological platforms used, site content and other resources are summarized in Table 9.

In 2005, WebCT was used to post administrative data (such as contact information), course content (online module, presentations, references, videos and links), formative evaluation (self-administered quizzes), and to allow asynchronous discussion between students, faculty and the course director. The course schedule and objectives were also posted on an additional website, the electronic portal used by all courses in the pre-clinical portion of the undergraduate medical program.

In 2006, course content was migrated to a new website created using qWeb, a cross-platform, open-source content management system developed by the medical education technology unit of the Queen’s School of Medicine (MedTech). The website included a learning map consisting of schedule information, objectives, and a detailed syllabus identifying the required advance preparation for each classroom session. Simple online modules were created using hyperlinked web pages to guide students through
content material formerly delivered in lecture format. Interactive formative assessment questions and exercises were added to the site using third-party freeware: Hot PotatoesTM (Half-Baked Software Inc) and Eclipse Crossword (©Green Eclipse).

One drawback to qWeb was a lack of specific functionality such as a discussion forum, gradable quizzes and delayed file release. A stripped-down version of the course WebCT site was maintained in order to provide asynchronous discussion as well as a formative multiple-choice exam. Students continued to access their schedule using OCR; this was also used to provide delayed release of notes from some classroom sessions.

Student feedback was helpful in streamlining and simplifying the course website for the 2007 version of the course. WebCT was abandoned completely because an online forum, newly implemented by MedTech, was now available, providing a tool permitting asynchronous online collaboration and discussion. Course content modules were reshaped using a new technological platform, Thinking Cap® Studio (Agile Software), an online e-learning authoring system. These modules were able to incorporate multiple-choice and short-answer questions, both with automated feedback capabilities.
Table 7. Time Allotted to Different Instructional Methods (including Pain teaching)
Instructional time expressed in minutes (% scheduled instructional time)

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total didactic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lectures – single teacher</td>
<td>1980 (75%)</td>
<td>1650 (64%)</td>
</tr>
<tr>
<td></td>
<td>- Symposia – team taught</td>
<td>720</td>
<td>810</td>
</tr>
<tr>
<td></td>
<td>- Presentations – student taught</td>
<td>1110</td>
<td>840</td>
</tr>
<tr>
<td>TBL</td>
<td>660 (25%)</td>
<td>930 (36%)</td>
<td>900 (40%)</td>
</tr>
<tr>
<td>Total classroom time</td>
<td>2640</td>
<td>2580</td>
<td>2250</td>
</tr>
</tbody>
</table>

Table 8. Time Allotted to Different Instructional Methods (excluding Pain teaching)
Instructional time expressed in minutes (% scheduled instructional time)

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total didactic – minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lectures – single teacher</td>
<td>1590 (71%)</td>
<td>1170 (56%)</td>
</tr>
<tr>
<td></td>
<td>- Symposia – team taught</td>
<td>720</td>
<td>810</td>
</tr>
<tr>
<td>TBL</td>
<td>660 (29%)</td>
<td>930 (44%)</td>
<td>900 (40%)</td>
</tr>
<tr>
<td>Total classroom time</td>
<td>2250</td>
<td>2100</td>
<td>2250</td>
</tr>
</tbody>
</table>
Methods of Student Assessment

Over the course of the study period, there were major changes to the evaluation structure of the MSK course. These are outlined in Table 10. In the first year, 75% of a student’s final grade was based upon end-of-term multiple-choice and short-answer examinations questions. These questions were administered as part of comprehensive examinations including content from all courses taken during the winter term of first year.

During the second and third year of the study, the examination weightings dropped significantly to 50% (2006) and 40% (2007). There was a corresponding rise in the proportion of the grade determined by TBL activities, which was 13% in 2005, 37.5% in 2006 and 40% in 2007. Peer evaluation was used in all 3 years of the study. Students assigned marks to their team members based on their contribution to team functioning and learning. These peer grades were pooled to develop a composite peer evaluation score for each student. In the first 2 years of the study, the peer evaluation score was applied as a multiplier to the group marks, raising or lowering the team portion of student grades. In the third year of the study, the peer grade was only applied if it raised the team grade. While students with negative peer scores did not lose any grades
Table 9. Course Resource Material by Year

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Website</td>
<td>WebCT:</td>
<td>WebCT:</td>
<td>qWeb:</td>
</tr>
<tr>
<td></td>
<td>Cases</td>
<td>Discussion board</td>
<td>Contact information</td>
</tr>
<tr>
<td></td>
<td>Contact information</td>
<td>Formative exam</td>
<td>Modules (12) with embedded formative</td>
</tr>
<tr>
<td></td>
<td>Discussion board</td>
<td></td>
<td>quizzes</td>
</tr>
<tr>
<td></td>
<td>Links (references, websites)</td>
<td></td>
<td>Learning map</td>
</tr>
<tr>
<td></td>
<td>Module (1)</td>
<td></td>
<td>Presentations/notes</td>
</tr>
<tr>
<td></td>
<td>Objectives</td>
<td></td>
<td>Link to MedTech</td>
</tr>
<tr>
<td></td>
<td>Presentation/notes</td>
<td></td>
<td>discussion forum</td>
</tr>
<tr>
<td></td>
<td>Quizzes</td>
<td></td>
<td>Question of the week</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td></td>
<td>References</td>
</tr>
<tr>
<td></td>
<td>Schedule</td>
<td></td>
<td>Video clips</td>
</tr>
<tr>
<td></td>
<td>Videos</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Online Course Resources:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Schedule</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Objectives</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Chapters from 3 textbooks</td>
<td>Chapters from 2 textbooks</td>
<td>Chapters from 2 textbooks</td>
</tr>
<tr>
<td></td>
<td>Outline notes (120 pages)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
in 2007, the score and grouped anonymous peer comments were fed back to each individual at the end of the course.

In addition to TBL-related grades (both individual and group) and end-of-term exams, students submitted an individual assignment in all 3 years. This case-based task replaced previous didactic teaching about osteoporosis, requiring students to use the Information Literacy skills acquired in the fall term to research this disease and its management. While the specifics of this assignment changed over the course of the study, the essence of the task remained the same. The grade assigned to this task was higher in the second and third years than in the first.

In the first and third years of the study, the course evaluation scheme included group assignments requiring students to work together outside of scheduled classroom TBL time. While the weighing of this was the same (5%) in both years, the 2005 project was quite substantial (a research-type poster and classroom presentation about a pain-related topic) in contrast to that in 2007 (development of a patient information handout about osteoporosis). Students were encouraged to collaborate asynchronously using the discussion board for the latter task.
Table 10. Assessment of Student Achievement and Grade Weightings 2005-2007

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual Tests</td>
<td>7%</td>
<td>12.5%</td>
<td>10%</td>
</tr>
<tr>
<td>Individual assignment</td>
<td>5%</td>
<td>12.5%</td>
<td>10%</td>
</tr>
<tr>
<td>Participation in online discussion</td>
<td>N/A</td>
<td>N/A</td>
<td>5%</td>
</tr>
<tr>
<td>Expanded clinical skills attendance</td>
<td>2%</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Group grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group Readiness Assessment Tests</td>
<td>6%</td>
<td>12.5%</td>
<td>30%</td>
</tr>
<tr>
<td>Group Application Exercises</td>
<td>N/A</td>
<td>12.5%</td>
<td>N/A</td>
</tr>
<tr>
<td>Group assignment (out-of-class)</td>
<td>5%</td>
<td>N/A</td>
<td>5%</td>
</tr>
<tr>
<td>Peer evaluation grade could modify team grade</td>
<td>Up/down</td>
<td>Up/down</td>
<td>Up</td>
</tr>
<tr>
<td>Summary of evaluation weighting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-course work</td>
<td>25%</td>
<td>50%</td>
<td>60%</td>
</tr>
<tr>
<td>• Individual grade</td>
<td>14%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>• Group grade</td>
<td>11%</td>
<td>25%</td>
<td>35%</td>
</tr>
<tr>
<td>End-of-term examinations</td>
<td>75%</td>
<td>50%</td>
<td>40%</td>
</tr>
<tr>
<td>• Multiple Choice Question exam</td>
<td>25%</td>
<td>25%</td>
<td>20%</td>
</tr>
<tr>
<td>• Short Answer exam</td>
<td>50%</td>
<td>25%</td>
<td>20%</td>
</tr>
</tbody>
</table>
Question #2

Historical Course Evaluation Data

Quantitative Data

A comparison of end-of-course student feedback surveys from 2005 and 2007 revealed a statistically significant improvement of student ratings of the course on all eight items common to both years (Table 11). Quantitative data from the 2006 course evaluation survey were not used due to administrative irregularities at the time of survey administration leading to some duplication of data. This did not affect the narrative portion of the survey, therefore all 3 years’ qualitative responses were analyzed (see the next section).

In 2005, the mean response for the statement “overall, this is an excellent course” was 3.35, which represents a neutral (“neither agree nor disagree”) rating. Two years later, the mean for this statement rose to 4.34, representing a point in between “agree” and “strongly agree.” There is a parallel reduction in standard deviation associated with this question from 1.027 (2005) to 0.621 (2007). While the larger response rate in 2007 (90%) in comparison to 2005 (52%) may be partially responsible for this change, this may also suggest greater clustering of opinion around the more positive answer in the most recent survey.
Of the eight items compared, all but one in the 2005 survey averaged a score of less than 4 (agree). In contrast, in 2007, all but one item averaged a score greater than 4. The one item that averaged between 3 and 4 in both years was the statement “the workload in this course was reasonable and appropriate.”

**Analysis of Narrative Responses**

During the period studied, several themes emerged from student narrative comments on the end-of-course surveys. These are summarized in Table 12. The tone of the narrative changed over the study period. In 2005, feedback was generally negative. Students felt that TBL was an ineffective instructional method and had concerns about the organization of the course. The website was felt to be confusing and students had difficulty identifying how to prepare for each classroom session. A definite preference for more traditional types of instruction was expressed.

The classroom used for TBL was identified as an obstacle to success because of space limitations. While students recognized that a large amount of effort had gone into the course design, they were particularly harsh in their evaluation of me as course director. For example, “Dr. Davidson is by far the worst instructor I have ever had at the university level” (CES0511). The following year was notable for a positive shift in student opinion of the course. TBL was now described in mostly positive terms, as were
the web-based modules. Students were appreciative of the work that had gone into the course and were much more positive towards me, personally. “I appreciate that you care so much about our learning – so far, you’re the most involved and conscientious professor we’ve had – Thanks!” (CES0630)

The biggest set of student complaints revolved around the use of multiple websites (WebCT, the MSK qWeb site and OCR) and resultant difficulty accessing printable course notes. Students were particularly frustrated when course notes were posted using a delayed release following the relevant classroom session. This group of students expressed concerns about the classrooms used during the course: the gym had poor acoustics, poor visibility and uncomfortable chairs. The gym had been used as a venue for half-day teaching blocks, including some lectures and symposia, and this was felt to be particularly problematic for these types of teaching.

Student opinion of the course was enthusiastically positive in 2007. “I have never learned so much in a semester before! I think this course changed the way I approach learning” (CES0748). The course was felt to be well organized with clearly stated expectations. While students noted an increased workload, they indicated that there was an educational “pay off.” For example, MSK was described as a “very good course, more work but better in the long run, team learning was good” (CES0728). The online
Table 11. Comparison of Common Course Survey Items from 2005 and 2007

<table>
<thead>
<tr>
<th>Study year</th>
<th>n=</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>t</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overall this is an excellent course</td>
<td>2005</td>
<td>52</td>
<td>3.35</td>
<td>1.027</td>
<td>-6.370</td>
</tr>
<tr>
<td>2007</td>
<td>90</td>
<td>4.34</td>
<td>0.621</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I learned a great deal from this course</td>
<td>2005</td>
<td>52</td>
<td>4.00</td>
<td>0.840</td>
<td>-3.467</td>
</tr>
<tr>
<td>2007</td>
<td>90</td>
<td>4.34</td>
<td>0.640</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The course was helpful in developing new skills</td>
<td>2005</td>
<td>52</td>
<td>3.60</td>
<td>0.846</td>
<td>-3.819</td>
</tr>
<tr>
<td>2007</td>
<td>90</td>
<td>4.12</td>
<td>0.684</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I felt that this course challenged me intellectually</td>
<td>2005</td>
<td>52</td>
<td>3.69</td>
<td>0.829</td>
<td>-5.092</td>
</tr>
<tr>
<td>2007</td>
<td>89</td>
<td>4.33</td>
<td>0.636</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. My interest has been stimulated by this course</td>
<td>2005</td>
<td>52</td>
<td>3.63</td>
<td>1.067</td>
<td>-2.499</td>
</tr>
<tr>
<td>2007</td>
<td>88</td>
<td>4.06</td>
<td>0.902</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. The course covered the right amount of material</td>
<td>2005</td>
<td>52</td>
<td>3.58</td>
<td>0.936</td>
<td>-3.605</td>
</tr>
<tr>
<td>2007</td>
<td>90</td>
<td>4.11</td>
<td>0.678</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. The workload in this course was reasonable and appropriate</td>
<td>2005</td>
<td>52</td>
<td>3.10</td>
<td>1.089</td>
<td>-3.246</td>
</tr>
<tr>
<td>2007</td>
<td>90</td>
<td>3.68</td>
<td>0.992</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. The course material was presented at a satisfactory level of difficulty</td>
<td>2005</td>
<td>52</td>
<td>3.60</td>
<td>0.891</td>
<td>-4.723</td>
</tr>
<tr>
<td>2007</td>
<td>89</td>
<td>4.24</td>
<td>0.523</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
modules were popular for preparation, for self-assessment and for review. TBL was also seen as a positive experience that enhanced learning. Students commented that these aspects of the course enhanced their learning and allowed them to integrate and consolidate knowledge. In contrast, online asynchronous discussion, which focused around the “Question of the Week” activity, was unpopular and generally felt to be unhelpful. There were many comments similar to this one: the “discussion board seemed like a waste of time to me.” (CES0759).

While students continued to express frustration when notes were posted following a session rather than before, there were few concerns raised about the course website. There were several comments about TBL classrooms: the engineering classroom was unpopular because of poor visibility from the back of the room and because it felt cramped, but many fewer concerns were raised than the previous year. A number of students simply offered that they did not like moving between classrooms.

Student Survey Results

Response Rate

In 2005, 61 students (60%) of the class completed the research survey administered as part of this project. There were a similar number of respondents 66 (66%) in 2006 and 85 (85%) in 2007. Although administered 3 months later than the
course survey, patterns of response are similar, with 51% of students completing the
course evaluation survey in the first year and 90% of students completing it in the third
year.

Analysis of the survey is divided into four sections: comparison of attitudes to
instructional methodologies (items 1-15), student perception of achievement of course
objectives (items 16-21), ranking of the suitability of instructional modalities to achieve
educational objectives (items 22-32), and the most useful features of the active
instructional modalities used in the MSK course (items 33-34). In developing the student
research survey, the original intention was to group items by each of the three
instructional methods and generate scores that could be compared across the three
cohorts.

In order to determine the validity of this approach, a principal component
analysis was performed including the 14 items related to instructional methods. (Item 2
was taken from the Value of Teams survey where it was considered a distracter,
therefore it was not analyzed.) This identified two sets of items that grouped strongly
together (Table 13). The first component included all questions linked to TBL and online
learning; the second included questions linked to lectures. Because of this, items were
grouped to create two scores (rather than three) differentiating between student attitudes
<table>
<thead>
<tr>
<th>Theme</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online modules</td>
<td>“Internet computer teaching aids do NOT substitute for effective lecturing” (CES0501); “I don’t mind the online quizzes. I found that I did more reading and understood the subject, however I then found it very difficult to sit through a full lecture on the same topic.” (CES0508)</td>
<td>“I thought the modules were a good learning tool” (CES0603); “Online modules were very helpful for consolidating information” (CES0617); “will be great references over the next few years”(CES0630)</td>
<td>“I really liked the modules, interactive, lots of pictures, clinical examples and kept me on top of homework” (CES0724); “I really liked the online modules, but everything online could be easier to navigate.” (CES0754)</td>
</tr>
<tr>
<td>Classroom</td>
<td>“group based learning in a lecture hall does NOT work” (CES0501)</td>
<td>“Burr Gym is NOT a suitable classroom (poor air/too cold/hard to hear)!!” (CES0605); “Patio chairs are not comfortable when sitting for hours” (CES0620); “Burr gym is not a great classroom – we understand its purpose in TL sessions, but please make sure all lectures are in B139” (CES0655)</td>
<td>“Jackson Hall was awful, especially for those at the back” (CES0751)</td>
</tr>
<tr>
<td>Organization</td>
<td>“overall organization was a mess” (CES0502); “with so many instructors it must, at times be difficult for everything to run smoothly” (CES0518)</td>
<td>“ORGANIZATION IS NEXT TO GODLINESS. LEARN HOW PLEASE.” (CES0615)</td>
<td>“I think the MSK course was well organized” (CES0709); “Very well organized. I hope the rest of phase II courses are as well put together” (CES0708)</td>
</tr>
<tr>
<td>Theme</td>
<td>2005</td>
<td>2006</td>
<td>2007</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Team-based learning</td>
<td>“Group work: WE ARE NO LONGER IN ELEMENTARY SCHOOL! The group quizzes are useless – we all look up answers we didn’t know before we write and then waste valuable time in a pointless exercise” (CES0514); “in class quizzes were a waste of time” (CES05004); “I personally felt a lot of pressure to “collaborate” on the evaluation in order to ensure all group members received the same mark in the end” (CES0518)</td>
<td>“Team learning works well. I think that I learned a lot more than in a lecture” (CES0604); “I really liked the group learning method (I am dreading returning to lectures next week!” (CES0657)</td>
<td>“I loved the in-class group work and well define[d] studying before class” (CES0717); “The team based learning was one of the most rewarding learning experiences I have had in university” (CES0746); “I enjoyed the team learning – helped me retain the material better” (CES0706)</td>
</tr>
<tr>
<td>Website</td>
<td>“website is a pain to use; message board is awful, quizzes were good, resources in too many locations” (CES0515)</td>
<td>“Website was confusing” (CES0605); “Too many websites. It was very difficult to find what I needed and I often ended up coming to class without the notes I needed” (CES0604); “It would be more useful to combine all 3 sites into one.” (CES0618)</td>
<td>“Although the MSK website was well organized, it would be easier to just put the information on the MedTech [Online Course Resources] since we still have to use MedTech for other courses for information. Getting as much information as possible in one place would be great”(CES0753)</td>
</tr>
</tbody>
</table>
to active and didactic learning methods. Survey items were combined into two scores representing active learning (items 1 and 3-12) and didactic learning (items 13-15). All items were weighted equally to develop the two scores. A one-way analysis of variance (ANOVA) was then performed which demonstrated a significant difference in each of the two scores compared across the 3 different years of the study. (Some data sets were incomplete, therefore the response rates reported for the grouped data are slightly lower than those noted for the survey as a whole). As illustrated in Table 14, there was a deterioration of the scores for didactic learning over time (from midway between “neutral” and “agree” to just below “neutral”) with an improvement in the active learning scores (from midway between “neutral” and “agree” to “agree”).

**Educational Objectives**

Analysis of student rankings of the different instructional methods with respect to the 11 educational objectives that I had defined revealed significant changes over time. These results are summarized graphically in Appendix D. In 2005, three-quarters of the students surveyed identified lectures as the optimal method to organize material and guide student learning (Graph D1); lectures were also the top ranked method to give students a practitioner’s perspective (Graph D2) and to guide students through difficult
Table 13. Principal Components Analysis of Statements about Instructional Methodologies

<table>
<thead>
<tr>
<th>STATEMENTS</th>
<th>Component</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The ability to collaborate with my peers will be necessary if I am to be successful as a student.</td>
<td></td>
<td>0.668</td>
<td></td>
</tr>
<tr>
<td>2. I have a positive attitude about working with my peers.</td>
<td></td>
<td>Omitted</td>
<td>Omitted</td>
</tr>
<tr>
<td>3. The ability to work with my peers is a valuable skill.</td>
<td></td>
<td>0.689</td>
<td></td>
</tr>
<tr>
<td>4. Collaborating with my peers will help me be a better student.</td>
<td></td>
<td>0.781</td>
<td></td>
</tr>
<tr>
<td>5. Solving problems in a group is an effective way to practice what I have learned.</td>
<td></td>
<td>0.807</td>
<td></td>
</tr>
<tr>
<td>6. Solving problems in a group is an effective way to learn.</td>
<td></td>
<td>0.718</td>
<td></td>
</tr>
<tr>
<td>7. Working in teams in class is productive and efficient.</td>
<td></td>
<td>0.679</td>
<td></td>
</tr>
<tr>
<td>8. Group decisions are often better than individual decisions.</td>
<td></td>
<td>0.636</td>
<td></td>
</tr>
<tr>
<td>9. Solving problems in groups leads to better decisions than solving problems alone.</td>
<td></td>
<td>0.709</td>
<td></td>
</tr>
<tr>
<td>10. Online study modules are an efficient way to learn.</td>
<td></td>
<td>0.682</td>
<td></td>
</tr>
<tr>
<td>11. Online study modules are an effective way to learn.</td>
<td></td>
<td>0.696</td>
<td></td>
</tr>
<tr>
<td>12. Online study modules are an effective way to practice what I have learned.</td>
<td></td>
<td>0.543</td>
<td></td>
</tr>
<tr>
<td>13. Lectures are an efficient way to learn.</td>
<td></td>
<td>0.882</td>
<td></td>
</tr>
<tr>
<td>14. Lectures are an effective way to learn.</td>
<td></td>
<td>0.882</td>
<td></td>
</tr>
<tr>
<td>15. Lectures are an effective way to practice what I have learned.</td>
<td></td>
<td>0.719</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Year</td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------</td>
<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Didactic Learning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>61</td>
<td>10.24</td>
<td>2.28</td>
</tr>
<tr>
<td>2006</td>
<td>65</td>
<td>9.92</td>
<td>2.43</td>
</tr>
<tr>
<td>2007</td>
<td>84</td>
<td>8.98</td>
<td>2.18</td>
</tr>
<tr>
<td><strong>Active Learning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>60</td>
<td>37.37</td>
<td>6.51</td>
</tr>
<tr>
<td>2006</td>
<td>66</td>
<td>41.68</td>
<td>6.68</td>
</tr>
<tr>
<td>2007</td>
<td>84</td>
<td>44.21</td>
<td>7.90</td>
</tr>
<tr>
<td><strong>df</strong></td>
<td></td>
<td>2</td>
<td>207</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td></td>
<td>6.182</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Active Learning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>60</td>
<td>37.37</td>
<td>6.51</td>
</tr>
<tr>
<td>2006</td>
<td>66</td>
<td>41.68</td>
<td>6.68</td>
</tr>
<tr>
<td>2007</td>
<td>84</td>
<td>44.21</td>
<td>7.90</td>
</tr>
<tr>
<td><strong>df</strong></td>
<td></td>
<td>2</td>
<td>207</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td></td>
<td>6.182</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
topics (Graph D6). Online study methods were felt to be superior in encouraging reflection and integration (Graphs D4 and D9) and in allowing students to control, apply and assess their learning (Graphs D5, D8 and D10). The provision of feedback was also associated primarily with online study (Graph D7). TBL was ranked last in the categories of organization, guidance, reflection and control of learning, but it was the most commonly ranked method to strengthen communication and collaboration (Graph D11).

Of note in 2005 was the absence of predominance of any of the three instructional methods in bringing medicine to life for the students (Graph D3).

In 2006, student preference shifted significantly towards TBL and away from lecture-based learning and online study. Online study was identified as the optimal method to organize material by just over half of the students (Graph D1); this instructional method was also felt to be the most appropriate to allow students to control their learning (Graph D5). Opinion regarding the method best to guide students through difficult topics was evenly split between lectures and online study (Graph D6).

Similarly, TBL and lectures were identified equally as useful methods to provide a practitioner’s perspective (Graph D2), and online study and TBL were both identified as important techniques to help students judge the extent of their own learning (Graph D10).
This group of students identified TBL as the top choice for seven categories including: the provision of a practitioner’s perspective (Graph D2), bringing medicine to life (Graph D3), reflection (Graph D4), the provision of feedback (Graph D7), application of knowledge (Graph D8), integration (Graph D9), collaboration and communication (Graph D11).

The cohort of students surveyed in 2007 demonstrated a clear preference for TBL and loss of favour for lectures. TBL was ranked first in seven categories (bringing medicine to life, helping reflectiveness, feedback, application of knowledge, integration, judgment of extent of learning and communication/collaboration) and lectures were ranked last in eight categories. Online study was ranked first in the categories of organization (Graph D1), control of learning (Graph D5) and guidance (Graph D6).

Course objectives

There was no significant difference noted in student self-ratings of mastery of five course objectives related to MSK conditions. In all 3 years, the mean rating was in the neutral (“neither agree nor disagree”) category. The sixth course objective was related to understanding the principles of effective group work. The average rating for this question improved over time from 3.69 (in 2005) to 4.09 (in 2007), which was statistically significant (F=7.774, 0.001).
**TBL and Online Modules: Student Perspectives**

The major themes that emerged from the data are outlined in Tables 15 and 16. Student comments from all 3 years indicated that online modules enhanced their learning. The modules allowed and motivated students to prepare for class, to practice what they had learned and to self-assess their understanding based upon feedback. Students felt that the modules were useful to help them to identify gaps in their knowledge.

Over the course of the study, an increasing number of comments cited the focus and organization of the modules as strengths. An important theme was that of student autonomy: the modules were self-paced and could be used flexibly and selectively to improve understanding or review content based upon identified gaps in knowledge. Students also commented on the value of the modules as a resource that they would return to.

The most common theme identified in the first year from the narrative question dealing with TBL was that it was an unhelpful instructional method. While there were some indications of continued unpopularity in the second and third years, these were minor in comparison to the feelings expressed by students in 2005. The strongest themes emerging from the student responses in the second and third years were the value of
learning with peers, the ability to practice recently acquired knowledge, enhancement of knowledge and self-assessment.
<table>
<thead>
<tr>
<th>Enhancement of learning</th>
<th>2005:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“I really liked this, it forced you to read around and really understand a topic in order to answer the online quiz” (RS05142)</td>
</tr>
<tr>
<td></td>
<td>“Test myself, apply concepts. Cement vague knowledge from lecture” (RS05137)</td>
</tr>
<tr>
<td>2006:</td>
<td>“Focus on what is important – learn details better” (RS06150); “It summarized the information in one place” (RS06157); “prepare for lecture using the most succinct resources – most important stuff was easy to find” (RS06181);</td>
</tr>
<tr>
<td></td>
<td>“I could easily go back to things I didn’t understand &amp; integrate it” (RS06165); “solidify my knowledge” (RS06209)</td>
</tr>
<tr>
<td>2007:</td>
<td>“learn concepts thoroughly” (RS07227); “learn the material in an organized way” (RS07228); “consolidate background knowledge”; (RS07240)</td>
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<tr>
<td></td>
<td>“Recognize key points + get info effectively without having to search through many references” (RS07261)</td>
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<table>
<thead>
<tr>
<th>Ability to self-pace learning</th>
<th>2005:</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>“Learn at my own pace”(RS05103); “Use my time as I want” (RS05112)</td>
</tr>
<tr>
<td>2006:</td>
<td>“Review information at my own speed” (RS06154); “go through topics in my own time” (RS06188)</td>
</tr>
<tr>
<td>2007:</td>
<td>“Go at my own pace to fully understand the learning objectives” (RS07224)</td>
</tr>
<tr>
<td></td>
<td>“go through well organized info at my own pace – refer back to when needed” (RS07226)</td>
</tr>
<tr>
<td></td>
<td>“Set the schedule of my own learning and navigate through the learning objective[s]” (RS07283)</td>
</tr>
</tbody>
</table>
| **Self-assessment** | **2005:**  
| | “Excellent way to assess how much I have learned” (RS0594) 
| | “Evaluate whether I had learnt the material to the current depth, and identify areas that I need to work on” (RS05125) “learn with immediate feedback” (RS05109) “Find my weaknesses” (RS05146); 
| | **2006:**  
| | “focus on areas in which I needed the most practice” (RS06192) 
| | **2007:**  
| | “fill in gaps in my knowledge” (RS07255); “review and test myself” (RS07232); “Get quick feedback for my learning” (RS07270) |
| **Organization** | **2005:**  
| | none 
| | **2006:**  
| | “understand the basics and details on MSK topics, which were clearly organized” (RS06160) 
| | **2007:**  
| | “organize + partition information in a manageable form” (RS07266) 
| | [the online quizzes] “were more efficient + condensed than a 3 hr lecture” (RS07277) “piece and parcel a large amount of information in a purely factual way. It’s efficient.” (RS07286) |
Table 16. Major Themes Related to Team-Based Learning

<table>
<thead>
<tr>
<th>Peer learning</th>
<th>2005:</th>
<th>2006:</th>
<th>2007:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Collaborate, look at things from a different perspective” (RS05109); “interact with future colleagues” (RS05093); “Gain knowledge only from what others knew - knowledge was incomplete, so not my preferred way of learning” (RS05131)</td>
<td>“Learn from others” (RS06150) “Broaden my understanding of material thru exposure to group members experiences/reasoning” (RS06165) “Show others how much I know” (RS06193)</td>
<td>“Build knowledge thru interactions w colleagues” (RS07216) “get help from others” (RS07220) “consider other viewpoints” (RS07232)</td>
</tr>
<tr>
<td></td>
<td>2005:</td>
<td>2006:</td>
<td>2007:</td>
</tr>
<tr>
<td></td>
<td>“Excellent way to go over material that was presented. Can use it to teach if more organized.” (RS05094) “Do nothing that lectures didn’t already provide” (RS05139)</td>
<td>“consolidate my learning” (RS06162) “apply my knowledge – see if I could explain the knowledge to others (good test of understanding)” (RS06172) “Talk about more different cases which helps solidify the basics” (RS06211)</td>
<td>“apply + reinforce concepts” (RS07227) “expans my knowledge base” (RS07232) “challenge the way I thought about the material and consider other approaches” (RS07249) “come prepared to meet the expectations of my team and with and approach to the material” (RS07283)</td>
</tr>
</tbody>
</table>
Table 16 (continued). Major Themes Related to Team-Based Learning

<table>
<thead>
<tr>
<th>Practice what I’ve learned</th>
<th>2005: “use the knowledge I gained from online modules and apply it to patient cases” (RS05138)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006 “practice, apply, interact” (RS06178)</td>
</tr>
<tr>
<td></td>
<td>2007: “put knowledge to work, problem solve” (RS07216)</td>
</tr>
<tr>
<td></td>
<td>“apply concepts to real-life problems” (RS07230)</td>
</tr>
<tr>
<td></td>
<td>“Think about things + put it into practice” (RS07252)</td>
</tr>
<tr>
<td></td>
<td>“Practice what I’d studied and learn how other people study (like memory tricks). This was the best way to work on clinical scenarios” (RS07287)</td>
</tr>
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</table>

<table>
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<tr>
<th>Not useful</th>
<th>2005: “Waste time in class” (RS05239)</th>
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<tbody>
<tr>
<td></td>
<td>“I don’t learn effectively in small groups” (RS0595)</td>
</tr>
<tr>
<td></td>
<td>“Become annoyed and waste my time” (RS05119)</td>
</tr>
<tr>
<td></td>
<td>2006: “I absolutely hated it. The volume of information was large enough without having to worry about a competitive team environment” (RS06131)</td>
</tr>
<tr>
<td></td>
<td>2007: “Didn’t do anything. Could’ve been made into online modules. It let the “know-it-all” personalities to shine, but anyone who is reserved or shy was pretty much shut out of discussion.” (RS07238)</td>
</tr>
</tbody>
</table>
CHAPTER FIVE: THE TEACHER’S TALE

Prologue

In 1994, shortly after joining the School of Medicine as an assistant professor, I sat in my office across from the Chair of the Division of Orthopaedics. During the course of the conversation he mentioned that I might be interested in taking on the role of undergraduate educational coordinator. I started to say that I would consider this and then I stopped … clearly, from his expression, it was a rhetorical question. The job was mine.

At that time I was embarking on a career as a pediatric orthopaedic surgeon. My expertise lay in the area of broken bones, infants with clubfeet and intoeing toddlers. My skills involved diagnosing childhood musculoskeletal problems, straightening bent limbs, applying casts, and wielding power tools (safely) in the operating room. Along the way, largely by osmosis, I had learned how to behave like a physician. This meant knowing how to work well with others, developing the ability to communicate with a wide variety of people, learning to research and solve patient problems that I had never previously encountered, juggling many competing demands, advocating for my patients needs and (perhaps most importantly) learning, always learning. But … no one had ever taught me how to be a teacher.
And so I began to teach. For the first few years, my prime educational focus involved developing lecture content and resource material. In the mid-1990s, this involved the creation of 35 mm slides using PowerPoint with the help of the Medical Photography unit. The inclusion of pictorial content (photographs, x-rays) was particularly challenging, as digital imaging was not readily available. Thus the process of creating a lecture required a significant investment of time and money. Slides were not reproduced for students (as they are today) and so I also created narrative summaries of key course content to simplify note taking in class.

By the end of the 1990s, I had developed a series of undergraduate lectures and I had become comfortable speaking to an auditorium full of students. I now had 5 years of experience as an independently practicing pediatric orthopaedic surgeon and could “ad lib” and readily bring examples from my clinical life to the classroom. Students seemed to enjoy this approach, voicing appreciation for the practical, case-based sessions that I gave as well as for the provision of electronic and handout versions of the classroom material. In 1997, I received a teaching award from the Aesculapian (Medical Student) Society recognizing my efforts. During this time, I had become also an active member of the MSK course committee, and had led an initiative to begin streamlining the course
objectives, which lacked cohesion and included areas of obvious content overlap between sessions.

“Is Anybody Learning Anything?”

In August 2001, I was named MSK course chair. Suddenly, I was responsible for more than my own lectures. My job was to manage the course as a cohesive entity and I began to realize how difficult this was, given the fact that 25 teachers were contributing to the whole. But the pivotal experience came during a lecture on children’s fractures that I had given many times in the past. About three quarters of the way through the session, a brave student put her hand up and asked me to explain the word “reduction”. In the context that I was teaching that day, this meant the restoration of normal anatomy to a fracture or dislocation, a basic concept necessary to understanding all of the cases that I had included in my presentation. How much of my 2-hour lecture had this student failed to grasp if she had not known such a fundamental term? How many other students were in the same boat? If this was happening in my session, what was happening in all the other classes? Was anyone learning anything? Looking up from the podium towards the rows and rows of quiet, note-taking students, I had no way of knowing.

I attended a large, traditional medical school in another city, another century. I spent 3 years sitting in lecture halls and attending laboratory sessions. Much of what I
learned then has slipped away from me. Who were the good teachers? Not the ones that were simply memorable, such as the teacher who accompanied his lecture on the guitar or the dermatologist of questionable taste who showed us pictures of risqué tattoos, but the teachers who helped me learn. There was an elderly Histology technician who held incredibly useful tutorials at lunch where he related images of cellular structure to everyday items; the bladder’s transitional epithelium became footballs and suddenly I could remember what it was. There was our first year anatomy professor, who could bring the human body to life on the blackboard in coloured chalk and who managed to learn most of our names over the course of the year; gently, but pointedly he asked individual students questions (even those who sat in the back row, like me). There was a pathologist who had harnessed and reshaped an unruly second-year course by limiting the number of teachers and imposing organization and structure to the teaching that he coordinated. What made these teachers different?

When I took over as MSK course chair, the course consisted of a series of whole-class lectures. In the months preceding the course that year, I used course management software (WebCT) to archive copies of the lecturer’s PowerPoint presentations. The use of a course website was quite novel within the School of Medicine at this time. In addition to providing a central location for course notes, this was a useful exercise for me
as it gave me the opportunity to become familiar with the content being delivered by other teachers.

Previously, paper-based handouts had been collated, packaged and sold in the Campus Bookstore. I knew that many teachers revised their session a few days prior to their scheduled lecture. My use of technology was an attempt to avoid the mass printing of notes, which were commonly out-of-sync with what students saw in the classroom. Students appreciated the availability of presentations online, but they persisted in wanting hard copies and arranged as a class to have the notes printed in bulk. This led to significant dissatisfaction when inevitable last-minute teacher revisions resulted in differences between the projected and the printed slides. Minor differences were the source of passionate complaints.

The course came and went and I survived, but I remained troubled about the way it had unfolded, in particular about what I interpreted to be a generally passive approach to learning assumed by both students and teachers. The students were like Indiana Jones seeking treasure. The basement classroom had somehow become the “Temple of Knowledge,” each bulleted point conveying “The Truth.” Not quite 20 years previously, as a first-year medical student myself, I had exhibited the same sort pragmatism. Faced with a content-heavy, lecture-based curriculum, my classmates and I adopted similar
tactics focusing on classroom notes to learn what was necessary to pass multiple-choice examinations. By 2002 I had been an independently practicing physician for 8 years and had learned that real-life patients seldom presented with characteristic features and classic findings. Real-life patient problems were just that: problems, requiring a degree of effort and creativity to find a solution. And so began my first real efforts in course redesign. I was driven to action by a growing concern that students were relying far too heavily on their teachers’ interpretations of the subject matter. Motivated more by a sense that this was wrong rather than by any specific pedagogical knowledge, I began to imagine a course that would require student activity and engagement.

Early Attempts with Different Instructional Methods

The focus of this work is the evolution of the MSK course between the years of 2005 and 2007 during the implementation of TBL. Prior to that time, I spent several years developing web-based curricular materials (self-study modules, cases with reflective questions, formative quizzes and other exercises such as crossword puzzles). This was an attempt both to manage the course effectively and to deliver the content to the students using a variety of methods, hoping to engage them with the subject matter. It was evident that students were accessing the course material available online: from January to May 2004, the course website received over 2700 hits. Parallel attempts to
introduce active learning exercises into the classroom (lecture bingo, muddy points, student-led case presentations) were met with significant resistance. In the course feedback survey, students clearly indicated a preference for the didactic format. The novel format of the course was particularly problematic as it was scheduled immediately prior to high stakes end-of-term exams. Students felt pressure, not just from the MSK course preparation and assignments, but also from the weight of content from the whole term. Clearly, any future innovation in the course would be challenging in this time slot.

*Discovering TBL*

In reflecting on the 2004 implementation of the course, there remained “an emphasis on detailed content over conceptual knowledge, problem-solving and diagnostic clinical skills,” further noting that the evaluation system tended to “reinforce this and direct student focus and learning” (Davidson, 2004). Despite this, several lecturers noted that students “appeared to arrive better prepared for lecture than in previous years” (Davidson, 2004). My intuition suggested that, despite the apparent “failure” of the new strategies that had been introduced, active learning was something to be pursued while correcting obvious problems that had arisen in this iteration of the course. I presented my concerns and ideas to the Phase coordinator who agree to move the 2005 version of the MSK course to the start of term rather than the end.
I was introduced to TBL at a School of Medicine Education Journal Club in 2004. While initially skeptical of another educational fad, I was inspired to learn more about this instructional strategy by the enthusiasm of the presenter (who happened to be the Dean of Undergraduate Medical Education). Shortly thereafter, I read a book describing the method in detail (Michaelsen, Knight, & Fink, 2004). TBL seemed like a feasible solution to the problems that I faced, designing a course that would require (and hopefully inspire) student engagement and activity. With a little planning, it seemed that I could introduce some TBL components to the course while preserving some lectures, symposia and clinical skills sessions. As it appeared from my readings that one teacher in the existing lecture hall could accomplish this, there would be no need to recruit additional teachers, a perennial problem with small-group learning.

Much of the groundwork had already been done. The course objectives had been revised in 2002, informed by a quality assurance project that had correlated published objectives with the material presented in the classroom (Davidson, 2003). They were clear and well written and had been recently linked to an external standard (the Medical Council of Canada Examination Objectives). The course website included an electronic library of all teachers’ presentations and was organized into four distinct themes (injury, arthritis, pain and pediatric topics). There were existing resources including readings
from textbooks, articles, physical examination videos and self-study modules online. My intention was to continue using WebCT to deliver related material (cases, quizzes, online modules and presentations) to help students learn, practice and eventually master the course content. It did not seem feasible (or wise) to transform the whole course to this format in the first year; therefore, what resulted was a mix of lectures, symposia (often just several lectures back-to-back) and TBL. Individual and group assignments were also used to encourage students to work and learn beyond the boundaries of the lecture hall.

Over the course of the months preceding the 2005 course, I developed TBL content material (readiness assessment tests and group exercises). My initial focus involved the sessions that I taught personally, anticipating that other teachers in the course might be skeptical of the efficacy of the new approach. The content development took more time than I had anticipated. While creating the Readiness Assessment Tests (RATs) was no different than a standard multiple-choice test, design of the group application exercises was more complicated. I found the development of case-based exercises using Michaelsen’s 3S framework (same problem, simultaneous reporting, single answer) to be particularly difficult. As the first to introduce TBL within the School of Medicine, I had no local experience to tap into. While I had read and re-read
Michaelsen’s book, translating his method into specific tasks related to the course material was another matter.

2005: Year One

Shortly after New Year’s, 2005, I arrived in the basement classroom, computer and a briefcase full of papers in hand. I carefully marked out classroom locations for each of the 13 groups. As students arrived in class, there was some confusion and dissatisfaction relating to the imposed groupings and the seating plan. I heard later from a colleague that students had expressed dismay to her that they had been told where to sit. As the month wore on, certain groups became fragmented with members spread across the classroom. Over the course of the next 4 weeks, I experienced a sort of TBL “trial by fire.” The logistics were daunting, exams needed to be constructed to match special answer sheets, photocopied, marked by hand and the data entered electronically. Every day, it seemed, I was just keeping my head above water, making sure that I had the materials available for the next session.

Students arrived prepared for the TBL sessions and appeared engaged by the case-based material. The group tests and some of the group exercises appeared to fall flat as they were easily answered using the course notes, which I had allowed students to consult. It was therefore somewhat difficult to generate the type of inter-group
discussion described by TBL advocates. Nevertheless, there were many student
questions and a generally higher level of classroom discussion than I was used to when I
taught using a standard lecture.

Early on, it was obvious that the classroom space and configuration were
suboptimal. Just large enough for the class size, there was little space and fixed seating
that worked to undermine group communication, dynamics and functioning. I had a
difficult time circulating around the classroom during the session and the groups in the
centre of the room got little attention. Some students responded by moving out to the
adjacent cafeteria space during team application exercises.

Several of the TBL sessions were team taught with colleagues who had formerly
lectured. For each, the format was similar, and students would first engage in group
activities based upon structured cases and questions. My colleague and I would then
facilitate discussion of the answers and towards the end of the class (the original teacher
for the topic) would provide a short “debriefing” presentation. The latter was difficult to
gauge and tended to morph into a mini-lecture rather than being a commentary focused
on specific areas the students had found difficult to grasp. On several occasions, classes
ran over time.
Towards the end of the course, students were asked to evaluate their team members and assign a peer evaluation grade. I had scheduled class time for this, not realizing that students would immediately set about negotiating with one another. There was tremendous opposition to this process, which required students to differentiate (even by just a little) between high and low performing members of the team. One student approached me several days after the peer evaluation exercise, reporting that she had felt intimidated by her colleagues and had been pressured into assigning a favourable score when she actually felt that one of them had underperformed as a team member.

During the implementation of the course, I received a lot of student feedback, both formally and informally. In addition to the annual course survey, students handed in anonymous comment cards at the end of several sessions. I received over 150 emails from approximately half of the class outlining problems with WebCT, questions about online and in-class quizzes, clarification of course content and administrative details such as scheduling, assignments and course notes. The Centre for Teaching and Learning (CTL) had agreed to participate in an evaluation of the course, to give me an “arms length” opinion on the implementation of the new teaching strategies. One of the educational developers at the CTL observed four classes (two TBL and two lecture) and was able to comment on apparent student activity and engagement. In addition, she and
the Director of the CTL conducted focus groups with 11 students to explore their reaction to the changes in more detail.

Both the focus groups and the course survey results were disappointing. While students recognized the effort that had gone into the MSK course, they were harsh in their assessment of the results and of me in particular. Students felt that the course was disorganized, that expectations were unclear and that the website was a confusing nightmare. They felt overburdened by the course assignments and requirements for preparation in advance of class and expressed a clear desire for a return to lecturing. I was “by far the worst instructor,” both “deluded” and “inconsiderate.” TBL was “a pointless exercise” and a “waste of time.” I was particularly fascinated by an anonymous comment card following a session team taught with one of my surgical colleagues (he arrived dressed in ‘greens’, looking more the part than I did that day) who provided a “mini-lecture” debrief following the team application exercise. “It is incredibly rude and inconsiderate for you to have busy surgeons to come in to lecture, then have them wait while we do quizzes… Guest surgeons should speak first, and be allowed to get back to work. Stop wasting our time and theirs!”

The consultants from the CTL were more tactful in their recommendations. While they recognized the value of pursuing instructional approaches that promoted
active learning, they also identified significant areas for improvement. In addition to seeking out a new venue to teach and streamlining the website, they advised an improved introduction to the course laying out the rationale for the instructional design, a re-evaluation of assessment strategies and the inclusion of specific teaching about group processes and skills.

How can one little course eat up so much of my time? February 2005 … only 11 months to work further towards “getting it right.” Despite the negative feedback I had received, I could not face returning to 4 hours of lecture a day. Students were not generally happy, but they were no longer asking me to explain basic vocabulary halfway through class. There was more discussion, and discussion of problems with more substance, in the classroom. There was much discussion outside the classroom, by email, on the discussion board, in person. And then there were the students who stopped me as I was leaving the classroom to tell me how much they enjoyed learning by doing, how it forced them to keep up with the material and just how much they felt they had learned.

I had not been convinced of the efficacy of my previous (pre-TBL) attempts to introduce active learning into the classroom. By the end of the first year of this method, I recognized an increased level of engagement in the class as a whole and had clearly struck a positive chord with a few individual students. The hornets’ nest of discussion
that my intervention had stirred forced me to reflect on what had unfolded and critically assess what I could do to improve the course in 2006. I was not surprised by the negative feedback, as it had also seemed to me that some parts of the course had not worked. This reflection (and the negative feelings that came, inevitably, as I read the student feedback) spurred me to read more about TBL and seek guidance from colleagues and local educational experts. Guidance…. and support.

2006: Year Two

Clearly, some changes were needed: a better classroom (more room, table seating), revision of the website and ongoing development of the TBL cases. I sought support from my Department Head and the Dean of Undergraduate Education and received funding to redevelop the course website using a new platform (qWeb) developed by the MedTech unit. This allowed me to hire an assistant, a mechanical engineer who had developed a corporate online training program working with the Continuing Education group from the Faculty of Education. Together, we developed a new course website based upon existing lecture content. We created 12 online modules using a series of linked web pages. These incorporated core content, case examples, images and linked references. The website development tool that we had available lacked important functionality, providing little beyond the capability to build and link
static web pages. A number of crosswords, short ungraded quizzes, and other interactive
exercises were developed using freely available software. The course WebCT site was
 pared down and maintained to provide a course discussion board. Any documents that
required delayed-release were posted to the main student portal (Online Course
Resources or OCR), which the students accessed regularly for all other courses.

In June of 2005 I attended the 4th annual conference on Team-Based Learning in
Medical and Health Sciences Education at Wright State University. This 3-day event was
an opportunity to attend workshops to increase my knowledge and skills related to TBL
and to network with other teachers who had adopted the approach. Both the formal and
informal learning opportunities at the conference were excellent and I arrived back home
with a better understanding of what had gone wrong and what to do next. I found it
particularly motivating to hear stories of other teacher’s explorations of this method and
the results that they had observed in student performance.

As the second year of TBL approached, a completely new course website had
been developed. We created a course “learning map” which outlined both the schedule as
well as any required preparation, in-class quizzes or assignment due dates; students had
clearly described a need for this sort of consolidated syllabus in their evaluation of the
previous year’s course. Course content was now presented as online modules
incorporating text, images and case examples. Each module included formative evaluation questions that incorporated formative feedback. I made minor revisions to the readiness assessment tests and major revisions to the group exercises. I had initially avoided using multiple-choice questions in these exercises; however, attendance at the TBL conference had helped me to understand that this was the simplest way of enabling students to report back with succinct, comparable answers which could lead to inter-group discussion. The secret was the construction of case scenarios with some degree of ambiguity, usually reflected in the possible answers. Questions that incorporated at least two credible answers could lead to a rich inter-group discussion as student teams debated their respective choices.

I had hoped to use the former hospital cafeteria for my TBL sessions; it was a large open space with configurable tables and a window looking out over the lake. However, at the last minute I learned that it was unavailable as teaching space. The newly appointed pre-clerkship curricular administrative coordinator was instrumental in relocating the sessions to our second choice, an ancient hospital gymnasium. The provision of dedicated administrative support was welcome, allowing me to concentrate on curricular development rather than day-to-day course operation. In early January, I arrived at the gym, laden down with technology (computer, projector, audience response
system) and curricular materials (team folders, tests, answer sheets). As the CTL consultants had suggested, the introductory session included specific information about TBL, including the process and underlying rationale. At the TBL conference I learned that I had made some mistakes in my original implementation of this technique, particularly by allowing students to complete the readiness assessment tests “open book.” The first readiness assessment process went well. Students were interacting better when seated together at round tables and during the group test discussion was animated. As groups uncovered their (correct) answers, many tables “whooped” with joy.

While the gymnasium provided a large, reconfigurable space that was superior to the previous year’s lecture hall, it was a challenge to set up equipment for computer slide projection. There were other issues that became quickly apparent: acoustics were poor, the lighting was erratic and the room became hot and stuffy when occupied by 100 students. Students seated with their backs to the screen found it uncomfortable to reposition themselves whenever slides were shown. This became a particular problem during didactic presentations that followed TBL sessions; these had been scheduled in the gym to minimize students moving between classrooms.

The most noticeable improvements, from my point of view, were the team application exercises (Appendix E). Dissatisfied with the previous year’s experience, I
had created a new set of progressively revealed cases interspersed with multiple-choice questions to stimulate inter- and intra-group discussion. Students quickly learned to bring notes, textbooks and wirelessly enabled laptops to the session (fortunately, the hospital had recently added wireless internet access to public areas) and as I walked around the room students were engaged in looking up answers, reviewing course material and (perhaps best of all) explaining concepts to one another. This year, I was careful to structure the post-application exercise debrief as just that, a short summary of key points, complete with handout (posted electronically); no more “lecture-in-disguise”.

In 2006, one of the rheumatologists agreed to experiment with TBL in his teaching. Over the summer, we had created three online modules designed to introduce students to the fundamental concepts of arthritis. I now designed two TBL sessions that would extend this into the classroom. The rheumatologist consulted on development of both the online and the classroom material and he and I team-taught both sessions, which were well received. I think that his conversion to the method became complete when he won the course teaching award that year! In addition to the arthritis teaching, several other TBL sessions were team-taught. This enhanced the teaching experience for me. In addition to giving the students another individual’s perspective on the material (often from another discipline than my own), the presence of another teacher allowed me to
pause and listen more than I had previously. When there were two of us, we often stood across the classroom from one another and were able to identify when students at the back could not hear or if other problems arose. More than anything, team teaching was fun.

Another key strategy was the simplification of the grading process. Gone were the graded online quizzes and the clinical skills attendance mark. The group assignment had been eliminated and, staying true to Michaelsen’s original description of TBL, all group work was done in classroom time. I continued to use the individual assignment in which students researched osteoporosis based upon a fictional patient case. This created nice linkages to the Information Literacy teaching from the previous term and had been well received by students the previous year. The evaluation scheme had been adjusted to credit the students for the work done during the course (50% of the course grade, up from 25% the year before), with half of the in-class grade reflecting TBL work. In addition to streamlining evaluation for the students, this change simplified the administrative tracking associated with the course.

In 2006, I conducted the peer evaluation process electronically. Students completed evaluations of their team members in private without coercion. Despite the fact that team scores were uniformly high, students continued to object to the possibility
of having their grade reduced by the peer evaluation process and this remained an unpopular feature of the course. As the course came to a close, I awaited the results of the student course evaluation survey with trepidation. It seemed to me that the teaching had gone well, as students arrived prepared and seemed engaged with the material. Other teachers noted this as well, citing excellent classroom discussion during their sessions. It became apparent that students were using the learning map to guide their preparation, not just for the TBL sessions but for more traditional sessions as well. This ‘halo’ effect seemed to change the dynamic in didactic as well as TBL sessions. Despite the skepticism of the second-year class (which was well known on the student grapevine), the 2006 first-year class gave TBL good reviews. Criticism was focused upon the locale (the gym was better than the lecture hall for TBL, but it was still fundamentally uncomfortable for extended periods of time) and the multiple websites (qWeb course site, WebCT as well as the main medical student online portal, Online Course Resources or OCR) containing course-related material. The online modules that were created were generally well received, but our attempt to compensate for their reduced functionality by using the other platforms had back-fired and created another focus of student controversy.
2007: Year Three

Another year behind me, with another 11 months to plan for next year’s course. Again, the search for a more suitable classroom, this time strictly to be used for TBL sessions with all lectures in an auditorium. Although I had sworn not to spend another summer developing course content, the student concerns about the course’s electronic backbone were legitimate and something had to be done. The School of Medicine had recently acquired a site license for Thinking Cap® Studio, an online authoring tool used to create e-learning modules with interactive assessment capability. With the help of a web developer and a summer student, I translated our previous work to this new format (Appendix F). Each module had a standard format and navigation system, interactivity and formative self-assessment components. The course website was simplified and the use of WebCT was eliminated. Discussion groups were added by linking the course website to the School of Medicine online forums which appeared seamless to the students, even though it represented a different website. Course objectives were published on OCR as was the schedule, however all downloadable course references, notes and presentations were linked to from the learning map.

The course introductory session was similar to the previous year: the development of linkage to past and future components of the curriculum, an overview of
the website and of TBL as well as a sample RAT. I decided to create the teams in class as I had seen done at the Dayton TBL conference. Although I had initially been skeptical about the feasibility of this approach (students stood up and sorted themselves by criteria that I had defined; in this case, previous experience with MSK, years of university study and place of birth), it worked well and created a sense of energy and interaction in the classroom. At the suggestion of one of the 2006 students, we booked all TBL sessions into a large top-floor classroom/laboratory space in one of the Mechanical Engineering buildings. As with the gym, a drawback to this room was the lack of digital projection equipment.

Thus, January 2007 found me making my way across a snowy parking lot with computer, projector and a large carrier bag full of team folders and course materials. Despite a few glitches with the room (it was locked on the first day, there were barely enough chairs, and a huge ramp from an engineering research study occupied the centre of the classroom during the first session), it was by far the best space for TBL that I had encountered to date.

My general observations about the students were similar to the previous year. Attendance was excellent, as was preparation and class discussion. The “halo” effect was again noted in non-TBL sessions. Students remained lukewarm to online discussion tasks
that were used to promote out-of-class peer interaction around the course material.

Although this was an unpopular feature of the course, there were over 1000 posts to the discussion forum over the month, reflecting the presence of a small participation grade based on online activity. At the end of the course, students were again asked to evaluate the performance of their team members. Unlike previous years, the peer evaluation grade was used to raise the score of high-performing students, but students identified as lower performers did not lose marks. All students received their peer grade as well as aggregated, anonymous comments from all team members. This basically eliminated all serious opposition to peer evaluation.

It had taken me 3 years, but by the end of January 2007 I felt confident in the design and implementation of the MSK course. Student evaluation of the course was extremely positive but, perhaps more importantly, several other MSK teachers commented that the students were coming to class prepared and able to engage with the course content, even during traditional didactic sessions.

Two other courses (Palliative Care and Hematology) that were scheduled in the same term as MSK had recently begun to explore similar instructional techniques. When the students arrived at their Hematology TBL session towards the end of the term that year, they spontaneously re-formed their MSK teams.
At times it was challenging to persist in the face of some of the obstacles that arose as well as negative student feedback. However there were also breakthroughs where suddenly the innovations that I had been struggling to implement came more sharply into focus: experiencing application exercises as a learner during the TBL conference; the first time I created teams in class; witnessing a swell of energy amongst the students; reading student posts in the discussion forum that attested to their engagement with the material outside the classroom.

My experience watching students move from simply occupying space in a lecture hall to making learning happen by interacting with each other has changed the way I think about teaching. This experience has shown me that the students I teach will rise to the expectations that are set out, and that teaching to a room of individuals who have already begun the groundwork to learn is altogether a richer experience than lecturing to those who are encountering concepts for the first time. Although, at the outset, my intention was to shake the students out of their apparent passivity in the lecture hall, I think that the biggest change that I have witnessed is the change in my own thoughts about learning and how best to facilitate it.
CHAPTER SIX: DISCUSSION

Going to Sea

In 1937, Arthur Ransome published We Didn’t Mean to Go to Sea. Reflecting on my experiences described in the previous chapter recalls the plot of this novel: “While on vacation in East Anglia, four children, whose previous sailing experience is limited to dinghies, accidentally drift out to the North Sea after the rising tide causes their cutter to drag anchor” (Fantastic fiction, 2008). They “decide that it is safer to hoist the sails and go farther out to sea rather than stay near the shore” (Wikipedia, 2008). In some ways, the voyage that I have been on as a teacher – outlined in this thesis – feels something like that fictional experience. My original goal was to move out of the fog (student passivity) that seemed to characterize the didactic course that I had inherited. However, in moving away from this known shore, the waters I was sailing were uncharted, treacherous, and to some extent unintentional.

When I began to make changes in the instructional design of the MSK course, I had no conception of myself as an innovator; in fact I was scarcely acquainted with the term in the context used by Rogers (2003). And yet it seems that is what I am. Three years into the experience it appears that a positive change has been achieved – the students and I have reached more settled and altogether remarkable waters. Perhaps most
compelling is the knowledge that others have begun to adopt similar strategies within my School. This chapter revisits the three original research questions and uses the data gathered to make sense of what happened.

Educational Innovation and Change

The heart of this work is a reflection on educational innovation. Innovation of any type is a difficult process (Rogers, 2003) and new educational strategies may fail at the implementation stage for a variety of reasons (Silverthorn, Thorn, & Svinicki, 2006). At the outset of this project, I did not aim to innovate (or to be labeled an innovator) – rather my purpose was to shift student attitudes away from unquestioning acceptance of the black-and-white lecture content. By the time I embarked upon this project, I had enough experience to know the importance of coping with the shades of gray of real practice. I did not anticipate the nonlinear messiness that would ensue as I disrupted the status quo, nor did I understand that success would hinge on a process of slow learning, in context, over time, and that it was I, the teacher, who would do the learning (Fullan, 2001).

While it is intuitively obvious to anyone who has tried to implement a new curriculum that “content and pedagogy interact in complex ways” (Chickering & Gamson, 1987), only recently has complexity science been formally applied to
education. Complexity embraces the simultaneity of dyads traditionally considered distinct: knower and knowledge, research and education, even teacher and student. This approach to inquiry encourages the simultaneously examination of educational practice in combination with contextual factors in order to uncover what may be tangled in the intersection of the two (Van Melle, 2005; Davis & Sumara, 2006). The use of narrative data (my experiences, thoughts and feelings) and qualitative data (students’ reactions to the course and their experiences in it) help to flesh out shifting attitudes and beliefs about instructional methods and practices that are captured by the survey data.

The setting into which change was introduced was a critical element in this story; student expectations and reactions were driven by their experiences in the rest of the curriculum, stories from upper classes, the School’s IT structure and even the physical space used to teach. Each of these factors likely contributed to intentional and unintentional adaptations to the course as did the feedback received from each successive class of students.

The Evolution of the Musculoskeletal Course

The first question addressed by this study was to quantify and describe the evolution in the design and implementation of the MSK course between 2005 and 2007. Substantial changes have been demonstrated in the design and implementation of the
musculoskeletal course between 2005 and 2007. There was a net decrease in direct instructional time as well as a significant increase in the classroom time allotted for TBL, from 25% in 2005 to 40% in 2007. Most importantly, there was a net gain in student activities associated with active learning: reading, reflecting and talking/listening (Meyers & Jones, 1993).

The transformation of the course was a gradual process, initially involving sessions where I had direct control as primary teacher with subsequent expansion as other instructors began to accept a different approach. This allowed for the staged introduction of this instructional technique as I sought out further faculty development opportunities to learn more about TBL and e-learning (by reading, attending conferences and networking with other teachers) and gained experience over time.

There was also an evolution in the e-learning component of the course over the three-year period. While this reflected my learning curve in developing and using instructional technology, it also relates the growth of IT resources available within the School of Medicine over time. Much of the negative feedback received from students during the second year of the study revolved around the use of three different web-platforms to host course materials. This was a poor compromise made in an attempt to provide enhanced functionality of online resources. In retrospect, this was probably a
mistake, as I had not anticipated the significant level of student frustration that this strategy would generate. A larger issue that emerges from the data is my personal lack of knowledge and an institutional lack of resources toward the development of robust models of e-learning. As Harden comments, “e-learning implementation has to be monitored and managed by staff with the necessary education, technology and content expertise” (2008, p.1).

As the proportion of active learning sessions increased, there was a corresponding shift in the student assessment strategy de-emphasizing the importance of the final examination (from 75% of the course grade in 2005 to 40% in 2007). Students were rewarded for both individual and group effort with (often immediate) feedback both in and out of class. The combination of graded and ungraded formative assessment served to motivate students to change their behaviour and prepare prior to classroom sessions, something that I noted, as did other teachers in the course.

Student Response to the Changing Course

The second question, posed at the outset, was to describe the response of each cohort of students to the instructional changes in the MSK course. Over the course of the research period, there were no changes in the admission policies or procedures of the School of Medicine. The demographics of the three cohorts of students who participated
in the study were similar, although there was an increase in the proportion of female students from the first to the third year.

In other studies of undergraduate medical students, there has been a positive correlation between female gender and the introduction of integrated curricular units (Greenfield, Brown, Dawlatly, Reynolds, Roberts, & Dawlatly, 2006), therefore this may account for some of the positive shift noted in this study. It is, however, unlikely that all of the differences observed in student responses and attitudes stem from inherent dissimilarity in the three groups of students, given the small scale of the demographic differences between the three cohorts of students.

The response rates to both the course evaluation and the research surveys were significantly higher in the third year of the study. Anecdotal reports from participants suggest that students disenchanted with the course were less inclined to complete either survey (particularly in the first year). If this is correct, then one could hypothesize that the 2005 course evaluation survey actually overestimates the number of positive responses as students with negative opinions (of the course and the instructional methods) were less likely to be included in the results analyzed.

Student approval of the course, as measured by items taken from the standard course evaluation survey as well as by narrative comments, improved significantly
between the first and third year of the study. Had student feedback and opinion in 2005 been the only measure of success, active learning initiatives would have been abandoned. In addition to strongly positive ratings on seven of the eight items in 2007, six items demonstrated a reduction in the associated standard deviations suggesting a tighter consensus amongst respondents. One item, “the workload in this course was reasonable and appropriate,” received a rating below 4 in 2007. This is consistent with literature that identifies an increased workload for students with the introduction of active learning instructional techniques (McAlpine, 2004).

The research survey results provide data allowing the comparison of student attitudes towards didactic and active learning techniques. As the MSK course evolved over time, there was a statistically significant decrease in student approval ratings of didactic techniques and a parallel increase in ratings of active techniques. Students in the third cohort, who were exposed to the most mature version of the course, revealed a shift of preference away from the lecture as the optimal instructional technique with strong support for TBL and online modules. Students in particular valued the opportunity to control, assess and pace their own learning with online modules and to practice knowledge and learn from peers with TBL. These changes mirrored the growth of my expertise in and comfort with the altered course design.
Critical Elements that Influenced the Course Outcome

The final question central to this work was to identify the critical elements that influenced the course outcome as the instructional model matured over time. It is clear from the data presented above that not only did the MSK course evolve over the study period, but also there was a significant difference in the attitudes of students exposed to different iterations of the course. It is also evident that, at times, the ship sailed on stormy waters with significant and sometimes vitriolic student feedback.

The success of the course is judged from two perspectives: student feedback and student behaviour, the latter observed from the teacher’s vantage. In addition to the improvements in student opinion of the course, even in the first year of implementation, there was increased student preparation and interaction noted. Analysis of the data collected identifies key elements that appear to have influenced the course outcome.

These can be expressed in three distinct groupings: external factors, technology and the teacher.

*External Factors*

External support is often a critical factor in enabling educational transformation; a lack of institutional support may cause well-planned instructional interventions to fail
(Silverthorn, Thorn & Svinicki, 2006). Thompson and colleagues (2007) identified the importance of buy-in from both faculty and administrators as well as the availability of resources including expertise in the method, faculty preparation time for the development of TBL materials, appropriate classroom space and administrative support. Without buy-in from my Department head and Associate Dean, I would have had difficulty persisting in course redesign past the first year. Administrative support is a crucial element in fostering educational innovation (Silverthorn, Thorn & Svinicki, 2006).

In addition to moral support, local administrative endorsement extended to the provision of resources that facilitated the work of developing curricular materials (the course website) and the course administration (the introduction of dedicated administrative curricular coordinators). The success of this project as well as the difficulties of implementing this type of teaching in existing physical space has been recognized at a senior management level. Currently, our institution is planning the construction of a medical school building that would include classrooms suitable for TBL and other non-traditional instructional formats.

The expectations of the LCME accreditation surveyors were aligned with the philosophy underlying the course redesign (decreased didactic teaching, formative
assessment opportunities, as well as opportunities for students to work both
independently and collaboratively). This created an incentive for institutional support of
this project, another important factor in promoting the success of an innovation (Rogers,
2003).

Technology

Technology has been both a facilitator as well as a detractor of the MSK course
redesign. Faculty who introduce web enhancements to traditional courses usually do so
for pragmatic reasons, however the instructional potential of this method quickly
becomes apparent (Wingard, 2004). This was my experience the year that I became
director of the MSK course. In addition to increasing my contact with students because
of the use of email, technology allowed me to capture and collate the didactic
presentations that originally defined the course. By 2005, I had begun to use web pages
to deliver pre-packaged content as well as formative assessment. This became a critical
enabler for TBL as it allowed student preparation prior to class, thus allowing the
transformation of classroom interactions.

Early on, the use of technology also contributed to some student dissatisfaction.
This echoes the experience of other educators (Allen, Walls, & Reilly, 2008) who have
embarked upon similar projects. Van Melle noted that “the ease with (which) the
technology can be used for learning is an important factor to consider” (2000, p. 87). The dissonance between the available University IT resources and an evolving, homegrown School of Medicine learning management system (LMS) created a dilemma for me. While the former included greater interactive functionality, the latter was more widely accepted by the students. My attempts to combine both systems – prizing functionality over ease of use - led to student frustration and general unhappiness.

The Teacher

My efforts in course redesign were stimulated primarily by inner motivation. I was driven to action by dissatisfaction with the level and quality of student interaction that I had experienced as a teacher. My own experiences as a student helped mold the directions that I chose to explore: the changes that I have been responsible for echo the good experiences that I recall from my own education.

I suppose that I could characterize myself as a risk-taker (choosing to enter a male-dominated specialty, Orthopaedic Surgery, in the mid-1980s attests to that) and therefore willing to venture into unknown instructional territory. The characteristics of a sense of moral purpose, risk-taking and “venturesomeness” have been associated with those likely to innovate and engender change (Fullan, 2001; Rogers, 2003; Searle, Haidet, Kelly, Schneider, Seidel, & Richards, 2003).
I found it particularly useful to develop expertise in TBL by attending a conference devoted to the use of this method in Health Sciences Education in 2005. In addition to hands-on sessions, this opportunity allowed me to connect with an international community of educators interested in sharing their experiences. My understanding of both the technical and pedagogical principles of e-learning also grew over the course of the project, often in direct response to problems and challenges that arose from student feedback about the website and online modules.

There were times when it was difficult to persist in the face of strongly negative feedback. However, I was sustained by what I was witnessing in the classroom. Although I had no way of measuring it, every day that I stood in the classroom with 100 students, the interactions were subtly different. There was more noise, more questions, more peer interaction and, generally, a higher level of discussion than I had ever seen before.

Searle and colleagues (2003) reviewed the initial implementation of TBL in medical education in 10 institutions. These authors noted an observable facilitation of both teaching and learning which motivated many teachers to continue. While the personal feedback that I received face-to-face was also encouraging, it was truly the
transformation of the group experience that prevented me from returning to an easier, more traditional dispensation of knowledge from the front of the room.

Charting the Correct Course

“The extent to which there is a ‘fit’ represents the extent to which students are receptive to learning within a given instructional environment. Theoretically fit is optimized when an equilibrium or balance exists between the students and the teaching context” (Van Melle, 2000, p. 2). During the early phase of this study, the new instructional model was something of a square peg trying to fit into a round hole. As students constructed their knowledge of musculoskeletal medicine, I as a teacher did the same learning about TBL and online instruction, while also learning how to blend the two and what was actually feasible in the context of my course, school and university.

This chapter began with the analogy of a small sailboat in the fog. A truer representation of the situation pictures me (the course director) steering an ocean liner along a turbulent new course, with little ability to shift direction quickly. Palmer states that “teachers possess the power to create conditions that can help students learn a great deal” (1998, p.6). The experience outlined in this thesis reminds us that creating the conditions for effective change requires both adaptation and adaptability – a combination of stability and transformation (Van Melle, 2005). These processes take time and require
consideration of contextual complexity and the shifting of beliefs, along with the more obviously necessary development of curricular materials and expertise in new pedagogical approaches (Fullan, 2001).

This thesis outlines the successful transformation of one 4-week course within a 4-year professional educational program. Critics may argue with this claim of success, as there has been no objective measurement of superiority of the transformed course.

Roberts, Lawson, Newble, Shelf, & Chan, (2005) have advocated a similar instructional approach combining e-learning with large class integrated learning activities as a more resource-efficient alternative to PBL. These authors demonstrated no significant difference in student outcomes (compared with traditional PBL). Levine and colleagues (2004) noted an improvement in standardized test scores as well as a higher student perception of engagement following the introduction of TBL.

Ten Cate (2001) makes the point that changes in student behaviour stimulated by instructional change may be more significant than change (or lack of change) in test performance. Narrative data from both students and teacher in this study suggest that improved student preparation, interaction and increased “time-on-task” have resulted from the blending of e-learning and TBL.
There have been obvious practical and pragmatic lessons learned from examination of the transformation of this course. This experience also provides insight into a process of instructional change developed via an iterative process, informed by pedagogical expertise, student feedback and teacher reflection. As the experience of the MSK course has been shared at both administrative (Undergraduate Medical Education Committee) and pedagogical forums (Health Science Education Rounds; Faculty Development sessions), several other teachers have experimented with variants of TBL in the past 2 years. Wider dissemination of similar innovations will require institutional leadership. Central to this will be the provision of a sense of shared purpose and concrete support in addition to the development of policies supporting the use of instructional techniques that promote student engagement with learning (Chickering & Gamson, 1987).

The exposition of this journey traveled has been an opportunity to analyze both the transformation of a traditionally taught course and my own transformation as a teacher. Future research directions include the exploration of similar voyages initiated by innovative teachers as well as inquiry into the changes that occur in the behaviour and attitudes of the students who travel with them.
Other teachers interested in the experiences described herein may avoid some of the pitfalls that I have described in the preceding pages. But no two voyages are truly identical and, like the students they teach, teachers too must practice, experience and reflect to truly learn. They should not be afraid to adapt and shape these ideas to their own particular circumstance. They will undoubtedly make new and creative errors and missteps and grow stronger and wiser in the process. Perhaps most importantly, the ability to innovate is not only a reflection of an individual’s characteristics (as has been suggested), but rather a mindset and process that can be facilitated and fostered by the culture of an institution.
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<td>The Musculoskeletal Course: an overview, analysis and future directions</td>
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### Survey Items

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<tr>
<td>Overall, this is an excellent course.</td>
<td>USAT – mandatory</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>I learned a great deal from this course.</td>
<td>USAT – mandatory</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>This course was helpful in developing new skills.</td>
<td>USAT</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>I felt that this course challenged me intellectually.</td>
<td>USAT</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>My interest in the subject has been stimulated by this course.</td>
<td>USAT</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>This course included components that addressed my personal learning style</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
<td></td>
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<tr>
<td>It was clear to me what was expected of me in this course</td>
<td>USAT</td>
<td>Y</td>
<td></td>
<td></td>
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<tr>
<td>The objectives of the course were adequately explained.</td>
<td>USAT</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>This course covered the right amount of material.</td>
<td>USAT</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>The workload in this course was reasonable and appropriate.</td>
<td>USAT</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>The course material was presented at a satisfactory level of difficulty.</td>
<td>USAT</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>The course was well organized</td>
<td>USAT</td>
<td>Y</td>
<td></td>
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<tr>
<td>The course was organized in a logical sequence.</td>
<td>Similar to USAT</td>
<td>Y</td>
<td>Y</td>
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<td>I received timely and useful communications from the course coordinator</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
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<td>when necessary.</td>
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<td>Team teaching (i.e. multiple “expert” lecturers co-teaching a session) was</td>
<td>Similar to</td>
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<td>effectively used in this course.</td>
<td>USAT</td>
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</tr>
<tr>
<td>Instruction was well coordinated among the teachers who taught separate but</td>
<td>Similar to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>related sessions (e.g. the different components of arthritis).</td>
<td>USAT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I participated in more in class discussion in this course than in other</td>
<td>USAT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>courses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team discussion of the readiness assessment tests helped me to learn and</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>better understand the course material.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The use of the audience response units (“clickers”) helped me to learn and</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>better understand the course material.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The team learning exercises in class helped me to learn and better understand</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>the course material.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The lectures helped me to learn and better understand the course material.</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>The symposia effectively used cases, patients and expert panels to help me</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>learn and better understand the course content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The online discussion board helped me to learn and better understand the</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>course material</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I only used the online discussion board because it was required.</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>The inclusion of patients/parents in symposia and other sessions was</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>valuable. (wording slightly different 2006/2007)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The course web page was helpful and informative</td>
<td>USAT</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Survey Items</td>
<td>Source</td>
<td>2005</td>
<td>2006</td>
<td>2007</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
<td>--------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>The course website was easy to navigate.</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>The course learning map/outline provided the information that I needed to prepare for the class sessions.</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>The course website modules helped me to learn and better understand the course material.</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Web-based quizzes and interactive cases helped me learn and better understand the course material.</td>
<td>Instructor</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The on-line references linked to from the course website were helpful and informative</td>
<td>Instructor</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The individual assignment helped me to learn and better understand the course material.</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>The goals and objectives of the expanded clinical skills sessions were clear.</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>The patient partner expanded clinical skills sessions were helpful in improving my ability to perform a “screening” musculoskeletal examination.</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>The radiology expanded clinical skills session was helpful in improving my ability to understand simple radiographs and recognize different types of imaging.</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>The videos provided were useful resources that helped me learn how to perform focused upper and lower extremity musculoskeletal examination.</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Henry’s Clinical Surgery (required text) was worth the money I paid for it.</td>
<td>USAT</td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Survey Items</td>
<td>Source</td>
<td>2005</td>
<td>2006</td>
<td>2007</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>-----------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Cecil’s Essentials of Medicine (required text) was worth the money I paid for it</td>
<td>USAT</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I found the required chapters in Cecil’s Essentials of Medicine Essentials of Surgical Specialties to be valuable resources that aided my understanding of course material</td>
<td>Similar to USAT</td>
<td></td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>I found the required chapter in Essentials of Surgical Specialties to be a valuable resource that aided my understanding of course material</td>
<td>Similar to USAT</td>
<td></td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>I used an alternate text as my reference</td>
<td>Instructor</td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>The course was organized to develop linkages between the different MSK themes (injury, arthritis, pediatrics) as well as between the horizontal Medicine in Society components (Epidemiology, Geriatrics)</td>
<td>Instructor</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C: Research Survey

Dear students:
I hope that you will complete this survey, which will serve two purposes. The information gathered from your class as well as the MEDS 2009 class will be used in the further development of the MSK Course. Data collected will also be included in my M.Ed. thesis.
In particular, the survey asks you to describe your personal learning style (after Kolb’s description), and capture your perceptions of working with peers, working in teams, working individually using electronic learning aids as well as your subjective impression of the growth of your MSK content-specific knowledge after completion of the course. The survey is voluntary and anonymous and has been approved by the Faculty of Health Sciences Research Ethics Board. It will take you between 5 and 10 minutes to complete. Students who choose to complete the survey will return it to the class curriculum representative and receive a ballot. There will be a random draw for a $50 Campus Bookstore gift certificate once the surveys are submitted.
If you have any questions regarding the survey, please feel free to contact me (davidsol@kgh.kari.net, 544-9626), Assistant Dean of Undergraduate Education, Dr. David Holland (dh9@post.queensu.ca) or Chair of the Faculty of Health Sciences Research Ethics Board Dr. Albert Clark (clarkaf@post.queensu.ca).
Thanks, in advance, for your participation in the survey,

Dr. Lindsay Davidson
MSK Course Chair
Assistant Professor
Department of Surgery
Queen’s University
Part 1:
Please circle the number beside the phrase that best describes the extent to which you agree with the following statements:

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The ability to collaborate with my peers will be necessary if I am to be successful as a student.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. I have a positive attitude about working with my peers.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. The ability to work with my peers is a valuable skill.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. Collaborating with my peers will help me be a better student.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. Solving problems in a group is an effective way to practice what I have learned.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. Solving problems in a group is an effective way to learn.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. Working in teams in class is productive and efficient.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. Group decisions are often better than individual decisions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9. Solving problems in groups leads to better decisions than solving problems alone.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10. Online study modules</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
11. Online study modules are an efficient way to learn.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

12. Online study modules are an effective way to practice what I have learned.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

13. Lectures are an efficient way to learn.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

14. Lectures are an effective way to learn.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

14. Lectures are an effective way to practice what I have learned.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

15. I feel that I could evaluate a patient with a musculoskeletal injury or disease, and propose a differential diagnosis.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

16. I feel that I can select appropriate investigations for a patient with a musculoskeletal injury or disease and understand the relevance of the results.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

17. I feel that I can construct an initial management plan for a patient presenting with musculoskeletal injury or disease.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

18. I feel that I can identify preventative measures relevant to musculoskeletal injury and disease.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

19. I feel that I can anticipate, recognize and
treat complications related to musculoskeletal injury or disease or to the common therapies used in their treatment.

| 20. I have an understanding of the principles of effective group work. | 1 | 2 | 3 | 4 | 5 |
Part 2: For each of the following educational objectives, rank order the three listed educational modalities in terms of their suitability to achieve the stated goal. Rank the modality “1” if it is the most suited to achieve the objective and “3” if it is the least. If you feel that none of the described modalities achieve this goal, tick the fourth box.

<table>
<thead>
<tr>
<th>Educational Objective</th>
<th>Lecture</th>
<th>Team based learning</th>
<th>Online study module</th>
<th>None are helpful</th>
</tr>
</thead>
<tbody>
<tr>
<td>21. Organizes a large amount of material into a manageable learning experience.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Gives me a practitioner’s perspective.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. Brings medicine to life.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. Helps me become more reflective.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Allows me control of my learning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. Guides me through difficult topics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. Provides me with appropriate and useful feedback.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. Allows me to apply what I’m learning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. Helps me integrate my learning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30. Helps me judge the extent of my own learning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31. Strengthens my communication and collaborative skills.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part 3: Complete the following statements describing, in your own words, the most useful feature(s) of each type of educational modality from your perspective as a medical student.

32. Online study helped me to:

33. Team based learning helped me to:
APPENDIX D: Student Ranking of Instructional Methods by Educational Objectives
Graph D1: Organizes a large amount of material into a manageable learning experience (% responses)

**Lecture**

- Most: 54.4% (2007), 40.7% (2006), 40.7% (2005)

**TBL**

- Least: 73.7% (2007), 72.9% (2006), 72.9% (2005)
- Some contribution: 22.8% (2007), 20.3% (2006), 15.7% (2005)

**Online module**

- Least: 1.8% (2007), 5.1% (2006), 10.8% (2005)
- Some contribution: 22.8% (2007), 40.7% (2006), 62.7% (2005)
- Most: 26.5% (2007), 54.2% (2006), 75.4% (2005)
Graph D2: Gives me a practitioner's perspective (% responses)

**Lecture**

- **Least:** 9.6\% (2005), 29.8\% (2006), 34.2\% (2007)
- **Some contribution:** 21.5\% (2005), 22.8\% (2006), 25.0\% (2007)
- **Most:** 44.3\% (2005), 47.4\% (2006), 65.4\% (2007)

**TBL**

- **Least:** 27.8\% (2005), 29.8\% (2006), 34.6\% (2007)
- **Some contribution:** 21.1\% (2005), 27.8\% (2006), 42.3\% (2007)
- **Most:** 23.1\% (2005), 44.3\% (2006), 49.1\% (2007)

**Online module**

- **Least:** 38.0\% (2005), 38.6\% (2006), 50.0\% (2007)
- **Some contribution:** 36.5\% (2005), 50.6\% (2006), 57.9\% (2007)
- **Most:** 11.4\% (2005), 13.5\% (2006)
Graph D3: Brings medicine to life (% responses)

**Lecture**


**TBL**

- Most: 79.4 (2007), 70.0 (2006), 70.0 (2005)

**Online module**

Graph D4: Helps me become more reflective (% responses)

**Lecture**

- **Least**: 45.8% (2007), 37.3% (2006), 31.4% (2005)
- **Some contribution**: 31.4% (2007), 31.3% (2006), 34.1% (2005)
- **Most**: 4.1% (2007), 22.9% (2006), 31.4% (2005)

**TBL**

- **Least**: 14.9% (2007), 27.1% (2006), 37.3% (2005)
- **Some contribution**: 17.6% (2007), 27.1% (2006), 31.4% (2005)
- **Most**: 4.1% (2007), 22.9% (2006), 31.4% (2005)

**Online module**

- **Least**: 12.2% (2007), 27.1% (2006), 25.5% (2005)
- **Some contribution**: 35.6% (2007), 35.3% (2006), 35.6% (2005)
- **Most**: 28.4% (2007), 33.3% (2006), 39.2% (2005)
Graph D5: Allows me control of my learning (% responses)

**Lecture**


**TBL**


**Online module**

Graph D6: Guides me through difficult topics (% responses)

**Lecture**

- **Some contribution**: 25.5 (2005), 37.5 (2006), 42.0 (2007)
- **Most**: 65.5 (2005, 2006, 2007)

**TBL**

- **Least**: 62.5 (2005), 65.5 (2006, 2007)
- **Some contribution**: 27.3 (2005), 28.4 (2006, 2007)
- **Most**: 8.6 (2005), 12.5 (2006), 7.3 (2007)

**Online module**

- **Least**: 20.0 (2005), 19.6 (2006), 6.2 (2007)
- **Some contribution**: 35.7 (2005), 43.6 (2006), 28.4 (2007)
- **Most**: 64.6 (2005), 36.4 (2006), 65.4 (2007)
Graph D7: Provides me with appropriate and useful feedback (% responses)

**Lecture**

- Least: 25.5% (2007), 27.3% (2006), 47.3% (2005)
- Some contribution: 7.0% (2007), 30.2% (2006), 27.3% (2005)
- Most: 3.9% (2007), 11.7% (2006), 25.5% (2005)

**TBL**

- Least: 7.8% (2007), 9.3% (2006), 34.5% (2005)
- Some contribution: 39.0% (2007), 34.9% (2006), 38.2% (2005)
- Most: 54.5% (2007), 55.8% (2006), 53.2% (2005)

**Online module**

- Least: 7.8% (2007), 14.5% (2006), 27.9% (2005)
- Some contribution: 49.4% (2007), 34.9% (2006), 30.9% (2005)
- Most: 54.5% (2007), 42.9% (2006), 37.2% (2005)
Graph D8: Allows me to apply what I'm learning (% responses)

**Lecture**

- **Least**: 2007: 3.8, 2006: 16.7, 2005: 68.5
- **Some contribution**: 2007: 2.6, 2006: 13.0, 2005: 8.3
- **Most**: 2007: 75.0, 2006: 75.0, 2005: 8.3

**TBL**

- **Least**: 2007: 0.0, 2006: 10.4, 2005: 22.2
- **Most**: 2007: 80.8, 2006: 64.6, 2005: 29.6

**Online module**

- **Least**: 2007: 5.1, 2006: 14.6, 2005: 7.4
- **Some contribution**: 2007: 58.3, 2006: 27.8, 2005: 27.8
- **Most**: 2007: 76.9, 2006: 64.8, 2005: 64.8
Graph D9: Helps me integrate my learning (% responses)

**Lecture**

Least: 5.3% (2007), 22.0% (2006), 48.1% (2005)

Some contribution: 12.0% (2007), 29.6% (2006), 66.0% (2005)

Most: 6.6% (2007), 22.2% (2006), 88.2% (2005)

**TBL**

Least: 3.9% (2007), 14.3% (2006), 35.2% (2005)

Some contribution: 17.1% (2007), 22.4% (2006), 38.9% (2005)

Most: 25.9% (2007), 63.3% (2006), 78.9% (2005)

**Online module**

Least: 7.9% (2007), 21.7% (2006), 33.3% (2005)

Some contribution: 15.8% (2007), 28.3% (2006), 50.0% (2005)

Most: 13.0% (2007), 28.3% (2006), 53.7% (2005)
Graph D10: Helps me judge the extent of my own learning (% responses)

**Lecture**

- Least: 2007 - 60.8, 2006 - 62.5, 2005 - 60.8

**TBL**

- Most: 2007 - 19.6, 2006 - 43.1, 2005 - 60.0

**Online module**

Graph D11: Strengthens my communication and collaborative skills (% responses)

**Lecture**

- **Least**: 2005: 29.8, 2006: 36.6, 2007: 52.1
- **Some contribution**: 2005: 47.9, 2006: 53.2, 2007: 61.0
- **Most**: 2005: 0.0, 2006: 17.0, 2007: 17.0

**TBL**

- **Least**: 2005: 8.5, 2006: 31.9, 2007: 63.8
- **Some contribution**: 2005: 12.8, 2006: 2.4, 2007: 100.0

**Online module**

- **Least**: 2005: 63.8, 2006: 46.5, 2007: 61.0
APPENDIX E: Sample Application Exercise (used in 2006)
MSK Application exercises

1. Jason X., a 27-year old male inmate is brought to the Emergency room for
assessment. He reports that he banged his right hand against his metal bunk three
days ago and injured his left fifth knuckle. He presented to the institution
infirmary complaining of increasing hand pain and was sent to the hospital for an
x-ray and orthopaedic consultation. Upon arrival to the Emergency room, his
vital signs are:

   HR  85/mn
   BP  130/70
   RR  20/mn
   T    37.9 ° C

Mr. X is very reluctant for you to examine his right hand and is requesting
morphine for the pain. You convince him to allow you to examine his hand and
note the following:

   (photo of a hand with swelling in the area of the metacarpal head)
   Redness and swelling in the area of the metacarpal head.
   Extreme tenderness upon palpation of the distal half of the fifth metacarpal.
   The patient has no active motion of the fifth metacarpal joint. Passive motion is
   excruciatingly painful.

Part 1:

Based on this information, choose the ONE diagnosis that you are MOST
CONCERNED about from the following list:

a) Fractured fifth metacarpal
b) Dislocated fifth metacarpophalangeal joint
c) Osteogenesis imperfecta
d) Septic arthritis
e) Narcotics addiction

Two reasons why you chose this answer:

Part 2:
The radiology technologist arrives with the x-ray that she had taken just prior to your arrival. Which of the following best describes the positive findings on this x-ray?

a) Fractured fifth metacarpal with dorsal angulation  
b) Fractured fifth metacarpal with volar tilt  
c) Fractured fifth metacarpal with dorsal displacement  
d) Both a) and b)  
e) Both a) and c)

Part 3:

The nurse arrives with the cast cart, assuming that you would like to apply a cast. Just prior to applying the cast padding, you notice some yellow fluid draining from a 3mm laceration over his metacarpal head. Your next step would be to:

a) Apply a steri-strip to the laceration and proceed with closed reduction and casting of his hand.  
b) Take a culture from the laceration, proceed with closed reduction and casting of his hand and start antibiotics if culture result is positive.  
c) Omit the closed reduction for the time being and apply a dressing and a removable splint to his hand and start broad spectrum antibiotics.  
d) Take a culture from the laceration, leave the wound open and start broad spectrum antibiotics pending culture results.  
e) Order that the patient remain fasting and contact the operating room to book emergency drainage of his joint.

Reason why you chose this answer:
Amber B., an 11 year old girl is brought to the Emergency room by ambulance following a pedestrian-car accident. She was crossing Highway 2 near the library in Picton when she was hit by a car traveling at approximately 80 km/hr. She was found moaning by the side of the road and transported to hospital complaining of right leg pain.

Part 1:

Rank the following aspects of her emergency room evaluation in the order that you feel they should be performed (a indicates that this is the first evaluation, e is the last).

1. Examination of eyes
2. Auscultation of chest
3. Complete blood count
4. Neurovascular examination of foot
5. Blood pressure

Explain why you chose a:

Explain why you chose e:

Part 2:

Miss. B. is fully assessed by the trauma team. A detailed examination reveals the following findings:

HR  90/mn
BP 100/65
RR  20/mn
T 36.2 ° C

Her trachea is central, her chest is clear to auscultation and her heart sounds are normal. She is awake, alert and oriented to place, person and time but does not recall the accident. Her abdomen is soft and non tender. There is no tenderness or deformity of either upper limb, the left lower limb, pelvis or spine. She is noted to have a shorted right thigh with an extensive contusion along the medial surface and external rotation of the foot. Her skin is intact and her foot appears is pink and warm with a palpable dorsalis pedis pulse. She can dorsiflex and plantarflex her ankle and has intact sensation to light touch over the entire leg and foot.

Please review the accompanying x-ray. (xray of broken femur in a child)
6. Assuming that this is the only injury, what treatment would you recommend.

   a) Application of skeletal traction
   b) Closed reduction and casting
   c) Closed reduction and external fixation
   d) Closed reduction and intramedullary rod
   e) Open reduction and plate fixation
APPENDIX F: Sample Online Module (used in 2007)
Bone Morphology and Fracture Healing

Objectives

Upon completion of this module, the student will be able to:

1. Describe the primary functions of bone
2. Describe the structure of bone at the macroscopic and microscopic level
3. Identify the function of different types of bone cells
4. Describe fracture healing as a sequence of stages
5. Predict anomalies in fracture healing based on information about the patient, the fracture and other clinical modifiers

Reference

SEER online module (review of bone morphology, formation and skeletal structure) - individual webpages from this site will be referenced in the module.

Related websites and image collections

University of Ottawa Histology website

American Society for Bone and Mineral Research - Bone Curriculum

School of Anatomy and Human Biology - The University of Western Australia - Blue Histology webpage

Start by reviewing the following two webpages:

1) Functions of the Skeletal System and

2) Structure of Bone Tissue.

Based on your understanding of this material, summarize the key functions of the skeletal system: (Answer A1 on answer sheet)

Describe a pathological situation where one of the mechanical functions of the skeleton is disturbed. What long term deficit may result? (Answer A2 on answer sheet)
At the macroscopic level, bone is organized into cortical and cancellous bone. The metaphyseal and epiphyseal regions consist of cancellous bone. In these areas, bony trabeculae are arranged for maximum strength and have capacity to realign in the direction of an applied stress. This is an illustration of Wolff's law: "bone is deposited and resorbed in accordance with the stresses placed upon it". The diaphyseal areas of the long, tubular bones (femur, tibia, humerus, etc.) are made of cortical bone. These have a thin endosteal membrane lining the inner surfaces. All bones (with the exception of those portions that are intra-articular) are covered with periosteum on their outer surface. Periosteum (image Copyright Lutz Slomianka 1998-2004) is thickest in young children and may provide a degree of stabilization in certain pediatric fractures. Biochemically, the skeleton contains 65% inorganic elements (minerals) and 35% organic bone matrix. Three types of bone cells, osteoblasts, osteocytes and osteoclasts, function together to regulate mineral homeostasis in response to endocrinological and mechanical signals.

Review histologic specimens of the two types of bone tissue found in the skeleton by clicking on the links provided: cortical (a.k.a. compact - image Copyright Lutz Slomianka 1998-2004) and cancellous (a.k.a. spongy or trabecular) bone.

Bone healing is influenced by the potential and activity of the cells that line the surface of the bone (osteoblasts and osteoclasts). Based on this fact alone, the greater the surface area of bone involved in the healing process, the more rapid the healing is likely to be.

Which type of bone tissue will heal the fastest? (Answer A3 on answer sheet)

a) Cortical bone

b) Cancellous bone

Bone Cells

There are three types of cell in bone. Their functions are outlined below:

Osteoblasts

Osteoblasts line the inner (endosteal) and outer (periosteal) surfaces of the bone. Osteoblasts synthesize organic bone matrix (osteoid) and collagen. Osteoblasts also synthesize the enzyme alkaline phosphatase and initiate the process of mineralization. Osteoblasts represent the final stage of differentiation of pluripotential stem cell in the bone marrow. They typically live about three months before flattening to become metabolically inactive bone lining cells. About 10-15% of osteoblasts become osteocytes.

Osteocytes

The most abundant cell in bone is the osteocyte. The cells known as osteocytes are formed from metabolically inactive osteoblasts which have become entombed in a newly formed bone matrix during active bone formation. Osteocytes no longer secrete osteoid; however they do maintain their sensitivity to PTH and vitamin D and participate in calcium regulation. Osteocytes are interconnected by tiny channels called canaliculi.
Osteoclasts

Osteoclasts are multi-nucleated giant cells that resorb bone by enzymatic degradation. These cells are characterized by a ruffled border and lie in bone resorption pits called Howship’s lacunae. Osteoclasts are related to hematopoietic cell lines (monocytes, macrophages). Osteoclasts are seen in increased numbers in diseases with increased bone turnover.

How many types of bone cells can you identify in this histological slide? What biological process does it illustrate?
Bone is a composite material, consisting of inorganic and organic components as well as the cellular elements discussed previously.

**Inorganic matrix**

The inorganic matrix of bone consists of a calcium hydroxyapatite, which is in a crystalline structure. This serves to:

1. Mineralize the osteoid produced by osteoblasts,
2. Provide strength and hardness to the bone,
3. House the body's mineral reserves, including:
   - 99% of the body's calcium,
   - 85% of its phosphorous,
   - 65% of its sodium and magnesium

**Organic matrix**

Thirty-five percent (35%) of bone is organic. The organic matrix is composed of the bone cells that you have just learned about, and of protein. Ninety percent (90%) of bone protein is Type I collagen which has a triple helical structure, and ten percent (10%) consists of noncollagenous
proteins. Abnormalities of collagen formation may occur and lead to bone fragility. Watch a flash movie depicting the normal sequence of collagen synthesis on the American Society for Bone and Mineral Research Bone Curriculum webpage.

This newborn male is observed to have shortened, excessively bowed limbs. He cries with even gentle manipulation of his arms and legs. Xrays reveal multiple fractures in various stages of healing. What abnormality of bone could result in this clinical picture? (Answer A4)

Complete this gap-fill exercise to test your knowledge about bone cells.

This type of bone is found in abundance in the metaphyseal regions of long bones, contains irregularly arranged trabeculae and has an ability to remodel secondary to mechanical stresses.

Choose the correct answer: (Answer A5)

a) C Cancellous bone

b) C Cortical bone
Which of the following statements about bone matrix is CORRECT? (Answer A6)

a) □ Most of the collagen found in bone is Type II collagen
b) □ Calcium carbonate crystals act to mineralize osteid
c) □ The inorganic matrix of bone houses the body's mineral reserves
d) □ Osteoid is produced by osteocytes
e) □ The organic bone matrix is arranged in a crystalline structure

Before we discuss fracture healing, it is important to understand some basic principles about bone growth. Review this related webpage from the Association for Bone and Mineral Research, with a particular focus upon the growth of long bones, flat bones and bone remodeling. Make sure that you watch the movies that outline these three important processes.

Which of the following statements best describes the growth of long bones? (Answer A7)

a) □ Fibroblasts transform into osteoblasts and create woven bone which is subsequently reorganized into lamellar bone
b) □ Microscopic cracks are created by activity. These stimulate first bone resorption and subsequently bone formation.
c) □ Cartilage is transformed as the chondrocytes hypertrophy and eventually die; there is vascular ingrowth and mineralization resulting in bone formation.

Which type of bone growth is similar to fracture healing? If you are not sure of the answer, review the reference cited above. (Answer A8)

*Bone is a unique tissue as it is able to reform itself and does not heal with scar as other tissues do.

Stages of fracture healing

A fracture occurs when the continuity of a bone is broken and local blood supply is interrupted. If the overlying soft tissues are also injured, fracture healing may be delayed or disrupted, particularly in anatomic regions with decreased vascular networks such as the tibial diaphysis. Bone is unique in its ability to regenerate itself. Healing occurs via reactivation of embryologic processes resulting in the formation of bone not scar. Fracture healing can be described in three conceptual stages. An understanding of the timing and mechanisms associated with each stage is important in planning fracture treatment. The stages are:
Inflammation

This begins immediately after bone injury with the formation of a local hematoma or fibrin clot. There is local cell death where vessel disruption has resulted in ischemia - usually at the very ends of the fractured bone. Over the course of the next few days, this area becomes infiltrated by inflammatory cells and is characterized by local swelling and warmth. The inflammatory cells release lysosomal enzymes and other mediators that attract pluripotent cells to the area; they also act to remove necrotic tissue. Fibroblasts, mesenchymal cells and osteoprogenitor cells appear and may transform nearby tissues. The fracture is tender and may be grossly mobile to physical examination at this stage. Inflammation is at its peak 48 hours after a fracture.

Repair

The reparative phase begins a few days after the injury with the arrival of mesenchymal cells able to differentiate into fibroblasts, chondroblasts and osteoblasts. The repair phase persists for several months; it can be divided into two distinct phases: soft and hard callus formation.

1. "Soft callus" formation lasts for approximately six weeks from the time of injury. During this preliminary stage of repair, pain and swelling subside and bony fragments become united by fibrous and cartilagenous tissue. Woven bone is formed. While this creates some stability, the fracture may still angulate at this stage if not held with stable external support, such as a cast or external fixator, or internal support provided by plates, screws or intramedullary devices.
2. "Hard callus" formation - During this second stage of repair, woven bone is transformed into lamellar bone. This takes approximately three months.

Remodeling

Remodeling is the process by which bone is removed in tiny increments and then replaced by new bone. After a fracture, remodeling may continue for months or even years. The adult human skeleton continuously replaces itself at rate of 10-18% per year. The rate of remodeling is accelerated in children and during fracture repair. In addition to being an essential part of fracture healing, remodeling plays an important role in calcium homeostasis. During the remodeling phase the woven bone is converted to lamellar bone and the medullary canal is reconstituted. During this phase, bone responds to loading characteristics according to Wolff's law. Some angular deformity may correct during this stage in children with sufficient growth remaining (up to 50 per year of growth remaining).
Factors affecting bone healing

Various local and systemic factors affect the duration and effectiveness of the healing process. Abnormalities in any of these areas may lead to abnormally slow healing (delayed union) or failure to heal (non union). These include:

Systemic factors

1. Age: Children heal more quickly than adults; healing potential is decreased with advancing age
2. Nutrition: Poor nutrition and/or vitamin deficiency adversely affects healing
3. General health: Chronic illness depresses healing response (diabetes, anemia, systemic infection)
4. Generalized atherosclerosis: Decreases healing
5. Hormonal factors: Growth hormone enhances healing; corticosteroids depress healing
6. Drugs: Non steroidal anti-inflammatory drugs (e.g. ibuprofen) depress healing
7. Smoking: Decreases healing

Local factors

1. Degree of local trauma/bone loss: A comminuted fracture with more soft tissue injury is slower to heal
2. Area of bone affected: Metaphyseal fractures heal faster than diaphyseal
3. Abnormal bone (infection, tumour, irradiated): Slower to heal
4. Degree of immobilization of fracture: Motion at site delays healing

Disruption of vascular supply: Delays healing

Abnormal Healing in Bone

Although, in most cases, fracture healing proceeds uneventfully, there are certain situations when the outcome is not normal. Several patterns of abnormal healing are described in this section.

Fracture non-union

Healing is described as ‘delayed’ if union is not seen within the expected time after initial treatment. At the six month mark, an unhealed fracture is termed a "non-union". There are two types of non-union: atrophic, where little callus has formed and hypertrophic, where there is obvious callus but continued instability. Atrophic non-unions respond to bone grafting. This involves transplantation of the patient's own healthy bone, often from the iliac crest, to the non-union site. An alternative is the implantation of donor bone or an artificial bone substitute. Hypertrophic non-unions often result from increased motion at the fractures site. These improve with by surgical stabilization of the non-union. If a non-union persists and remains mobile, the fibrous tissue at the fracture site may undergo transformation into synovial cells forming a "false joint" or pseudarthrosis.
Stress fractures

Stress fractures are the result of an imbalance of bone formation and bone healing, usually in young healthy individuals involved in repetitive physical activity. Common sites include the tibia, metatarsal and femoral neck. The diagnosis is often challenging as plain radiographs may be negative or may reveal calcification only in the late stages of healing. Bone scans and/or Magnetic Resonance Imaging scans are frequently diagnostic. Treatment with immobilization is usually successful.

The red arrow points to a stress fracture in this patient's calcaneus

Reactive bone formation

Reactive bone formation isn't true "healing" but instead a response of the bone to an underlying abnormality. Review this link from the University of Washington School of Medicine to learn more about the different patterns of reactive bone formation. "Sunburst" or "onion skin" patterns are growing rapidly and so are classified as "aggressive", while more solid patterns of periosteal reaction (such as are seen in children's fractures) indicate slower growths that are likely benign.
This is an example of benign periosteal reaction seen as a normal part of fracture healing in a child four weeks after a supracondylar humeral fracture.
This child has an aggressive humeral osteosarcoma. The sunburst reactive bone formation shown in this image is growing so rapidly that there is not enough time for a layer of bone to form over the periosteum. This is indicative of an aggressive growth and suggests, albeit not conclusively, the presence of a malignancy. In this case, the sunburst pattern is caused by an osteosarcoma.
Review your understanding of normal and abnormal fracture healing

Check that you recall the normal sequence of fracture healing by unscrambling this mixed-up sentence. (Answer A9)

A 65-year old man slips and falls on ice resulting in a closed fracture of his tibia. The fracture line is short and oblique involving the middle third of the diaphyseal portion of the bone. He has a history of heart disease (triple-vessel bypass two years ago) and diabetes. He is a non-smoker with no prior history of fractures. Identify factors from the described scenario which may cause this patient to have a slow rate of fracture healing.

The patient is treated with cast immobilization. The xray seen above illustrates his fracture eight months after the injury. How would you describe his injury now? (Answer A10)

a) □ Healed fracture
b) □ Delayed union
c) □ Hypertrophic non-union
d) □ Atrophic non-union

You have now completed the Bone Morphology and Fracture Healing module!