Start by doing what's necessary, then what's possible, and suddenly you are doing the impossible.

- Saint Francis of Assisi

University of Alberta

THE DESIGN OF AN ELECTRONIC KNOWLEDGE MODEL (e-KM) AND

THE STUDY OF ITS EFFICACY

by

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Abstract

Objectives: To 1) develop an electronic Knowledge Model (e-KM) of a surgical procedure, and 2) investigate the efficacy of the model in knowledge acquisition. The main purpose of the study was to develop a knowledge model of a surgical procedure (cyst removal) in an electronic medium such that it would enhance knowledge acquisition of surgical skills and to then determine the efficacy of the model. This is based on the Fits-Posner stage theory of learning motor skills that has been adopted in many surgical teaching models.

Methods: Two randomized experimental studies were conducted in three phases; the total student sample size was 118 (Study 1=56, Study 2=62). In both studies, one group received face-to-face instruction from a professor while the second group employed the e-KM. Both groups were administered a multiple choice test. Analysis of variance (ANOVA), regression analysis and Pearson's correlation methods were employed to analyze data. Descriptive statistics were used to analyze the frequency of access and its impact on test scores. Reliability was determined with Cronbach's alpha.

Results: The results showed no significant difference ($p > .05$) between e-KM the computer model and the surgeon instructor. There was a significant correlation between access time to video and knowledge (significant r ranged from .68 to .86, $p < .01$); however, increased time on task increase test scores, thus having a positive impact on knowledge acquisition.

Discussion: Research findings indicate that e-KM performs as well as the human instructor and provides the additional advantage of unlimited online access through the Web while addressing many of the pressures currently plaguing medical schools such as limited resources (staff and facilities), cost of administration, access to knowledge, academic regulations, policies and competing curricula. Furthermore, e-KM provides a standardized teaching model, eliminating instructor variability and functioning as a dependable learning tool.

Conclusion: In this thesis, I addressed the efficacy of e-KM on knowledge acquisition. While there was no significant difference between e-KM and the surgeon instructor on knowledge acquisition overall, students who accessed the e-KM multiple times achieved higher scores.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Introduction

Ever since the Flexner Report 100 years ago (1), researchers have been attempting to construct an ideal teaching and learning philosophy for medical education. Universities are undergoing changes in the delivery of their curricula in an environment influenced by technology (2-8). The expectation of incorporating new knowledge and information into existing programs has created time pressures. Limited resources to staff and facilities, cost of administration, academic regulations and competing curricula have intensified the situation. The traditional teaching models provide one-time access to knowledge (9-11), i.e., didactic teaching combined with limited observational learning. Teaching clinical procedures via an electronic medium allows the observational component to be achieved more than once, thus providing a solution to accessibility and increasing learning opportunities (12-14).

The introduction of computer technologies provides support for a wide range of learning activities that broaden pedagogical horizons, enhance active learning, support cultural changes and increase resource sharing. There is substantial evidence supporting technology enhanced teaching tools in medical training programs (15-19). However, there is a gap in the investigation of its efficacy; this is particularly true in surgical education (20, 21).

Reznick and MacRae (8) addressed many of the current issues affecting surgery training; the lack of learning theory specific to surgery propelled them to borrow theories from other disciplines to structure their training model. They took the Fits-Posner stage theory based on learning motor skills, aptly called motor-skill theory and aligned their surgery teaching model accordingly. The three stage model is composed of a cognitive stage as the first stage of learning, an integration stage as the second stage of learning and an automation-of-skills stage as the third stage of learning. Based on this model, the surgical skill learning is initiated at the cognitive stage, with observation being a critical element.

The current practices of teaching and learning surgery predominantly follow the traditional model of observational and experiential learning methods; in a day-to-day learning environment, there is limited opportunity to observe many of the surgical procedures (22-26). The American Surgical Association Blue Ribbon Committee Report identified the limitations in the training for surgery and recommended using technology as a partial solution to address the gaps in training (27-29). An approach to clinical procedures partially taught in an electronic medium challenges traditional teaching methods. However, the observational component can be achieved through learning tools such as electronic Knowledge Model (e-KM), thus providing a solution to the time constraint issues and accessibility.

The proponents for technological innovations in surgical education argue for its establishment, presenting its virtues in terms of repeated access, time, availability, improvement in skills and knowledge. Current technology is sufficiently realistic to be a surrogate for actual observational and experiential learning in the operating room; adding the convenience of access promotes effective and efficient training. For example, virtual reality surgical simulators are classed as high fidelity and are used in basic laproscopic skills, carotid-artery stenting, endoscopic and transcurtaneous procedural skills (24, 26, 27, 29-31). Furthermore, since these educational scenarios are completely replicable and highly standardized, it is easier to review and evaluate performance (15, 26, 27).

Statement of Problem

Review of the published literature reveals gaps in efficacy studies of technology supported learning. Research has typically focused on attitudes, the impact on resources, the delivery of curriculum, a comparison of various teaching models, the impact on skills, assessment of skills, or reports of educational experiences as case studies (28, 29, 31-33). In order to address this gap in the literature, the research question, is "Can an electronic Knowledge Model (e-KM) of a surgical procedure enhance knowledge acquisition among learners?".

The objectives of the present study were to 1) develop an electronic Knowledge Model of a surgical procedure, and 2) investigate the efficacy of the model in knowledge acquisition. The purpose of the study was to develop a knowledge model of a surgical procedure (cyst removal) in an electronic medium such that it would enhance knowledge acquisition of surgical skills and to determine its efficacy. The focus of assessment was on the cognitive aspects of knowledge acquisition. The overarching research question proposed for the study and the sub-set of questions that followed provide insight into teaching models in medical education.

To effectively address the research question, an extensive literature review is presented in Chapter 2; in Chapter 3, the method and design of an electronic knowledge model and the assessment instrument is presented. Chapter 4 contains the data, results and analysis of the data. Chapter 5 concludes with discussion and recommendations.

CHAPTER 2: LITREATURE REVIEW

Process of Literature Review

To address the research question: "Can an electronic Knowledge Model (e-KM) of a surgical procedure enhance knowledge acquisition among learners?", and to design an e-Knowledge Model to Study its efficacy, an extensive literature review was carried out as the first step. It is an environmental scan of relevant material relating to the research objective. There are many practice models of the literature review process; for this study, the articles were assessed for quality, inclusion/exclusion criteria, date range of publication, type of articles and type of research.

Quality Assessment

Adopted from the guidelines formulated by the University of York, at the Centre for Reviews and Dissemination, the following quality assessment (QA) criteria are used in the present study.

{URL: http://www.york.ac.uk/inst/crd/crdreview.htm.}

1. Are the underlying assumptions made explicit?
2. Is the research design of the study made explicit?
3. Is it appropriate for the question being addressed in the study?
4. Are the participants in the study well-defined and representative of the target population?

5. Are the data measures, sources and collection methods considered appropriate and complete for the Study 1nvolved?
6. Are analysis of the data and interpretation of the findings appropriate?
7. Were potential confounders acknowledged and addressed?

Inclusion/Exclusion Criteria

Inclusion criteria

- Publications can include journal articles, committee reports, systematic reviews, case reports, books and conference proceedings.
- Research can include pilot projects, case studies, randomized controlled studies, cohort studies, prospective studies and retrospective studies.
- Journal articles with the following key words:
    - Surgical skill assessment
    - Medical Education
    - Learning theories
    - Assessment tools in Medical Education
    - Reliability and validity in Medical Education
    - Web, CD-ROM, video, tele-health, virtual reality, simulation, animation in medical training programs
- Date: Published between 1995-2009
- Language: English only
- Study Population: Human

Exclusion criteria

- Assessment tools designed external to medical schools
- Comparison of student behaviours and attitudes external to medical schools
- Comparison of learning styles external to medical schools
- Knowledge theories

Based on the above criteria, 1009 articles were found and were then narrowed to 600. Furthermore, these articles were grouped into:

- Medical Education and technology
- Medical Education and assessment (psychometric)
- Surgical skills teaching and learning
- Surgical skill assessment
- Surgical training and technology (Web, virtual reality, CD-ROM, tele-health, animation, simulation)

Databases

PubMed, MEDLINE, Ovid and ERIC databases were used in the literature search.

PubMed: Database from the U.S. National Library of Medicine covering medicine, nursing, dentistry, veterinary medicine, molecular biology and healthcare*{URL: http://library.ucalgary.ca/branches/healthscienceslibrary}*

MEDLINE: Covers the international literature on biomedicine, including the allied health fields and the biological and physical sciences, humanities, and information science as they relate to medicine and health care. *{URL:http://library.ucalgary.ca/branches/healthscienceslibrary}*

ERIC: Indexes journal articles, books, theses, curricula, conference papers, and standards and guidelines across all educational topics.

{URL: http://library.ucalgary.ca/branches/healthscienceslibrary}

The rest of this chapter is divided into three sections:

- Technology in Medical Education
- Learning Theories
- Measurement and Evaluation in Medical Education

Technology in Medical Education

Introduction

The application of clinical knowledge and the development of skills in surgery become challenging owing to the complexity and technique required within the discipline. Due to diminishing resources, achieving an ideal teaching and learning environment is proving to be difficult. Societal pressures, including cost-containment, access issues, time constraints, patient safety, reduction of medical error, and healthcare quality have become issues to be reckoned with (34-37). Furthermore, there has been a paradigm shift of lessening service obligations and limiting work hours within the training; legislated policies are instituted in most organizations (38, 39).

In order to deal with these challenges, universities have sought solutions in technology (40, 41) such as Web technology, CD-ROM technology, video technology, digital imaging, tele-health, virtual reality and robotics to facilitate education. Technology is used by simulating scenarios within the clinical context in surgery, promoting teaching effectively with consistency (18, 23, 42, 43). The most compelling support is gathered from the aviation industry (44). Technology and simulations are widely used in teaching and assessing knowledge, skills and attitudes in surgical education. Technology can be represented in many forms such as standardized patients, mannequins, robotics, animation, and bench models. In this section, the focus will be on technology supported simulation observed within surgical specialties. The principal technologies addressed are Web technology, CD-ROM technology, video technology, digital imaging, tele-health, virtual reality and robotics.

Technology Used to Deliver Medical Education Curricula

Key foci of Medical Education is in curriculum development and teaching (5, 45-48) As evidenced in the literature, computer technology is invading medical education, and as a result, the design and delivery of programs are changing (49-53). Many sub-specialties in Medical Education have utilized technology to address specific educational objectives in their curriculum. For example, Laparoscopic Surgery (18, 51, 54), Surgery (18, 51), Radiology (55, 56), Psychiatry (57, 58), Emergency Medicine (59-61), Family Medicine (62, 63) and Pathology (64-66) have all incorporated technology to support their teaching objectives. Varied forms of technology such as Web (32, 67), CD-ROM (68-70), tele-health (17, 71, 72), video (73), (74, 75) animation (76-78), digital imaging (79, 80), Personal Digital Assistant (PDA) (81, 82) and virtual reality (15, 83, 84), as well as WebCT, Blackboard and Illuminate as learning platforms are used to accomplish specific course objectives (85, 86).

Web

Web technology is used for the purpose of disseminating lectures, tutorials, 2-D images, 3-D images and textbook-based navigation in text format. It is also commonly used to initiate discussions. (49, 87, 88) The content on the Web is mostly text based. For example, course content, course objectives, exam scheduling and assignments are all information disseminated via the Web. Communication and interaction between the instructor and students are in both synchronous and asynchronous modes, and are mainly text-based. Web technology is described as a service made up of "web servers" that store and disseminate Web pages, which are rich documents that contain text, graphics, animations and videos to anyone with an Internet connection. (88, 89) In general, Web-based instructional formats are comprised of multimedia-enhanced learning tutorials supplemented by asynchronous computer-mediated conferencing for case-based discussions. (32, 90-92)

Web technology is ideally suited for communication, dissemination of course content and scheduling. If audio and video bytes need to be made available, technical issues such as transmission speed and machine capacity could pose a problem (88, 93). However, the benefit of accessibility at no cost outweighs the hurdles.

Video

Video technology is used to capture and transmit a full-length movie or a short movie clip. It can refer to an analog VHS videotape or to a digital format such as a DVD or computer file. Video technology is used to assess performance of students and to provide feedback. Comparison of different learning models are also performed. (94-96)

Typically, students are videotaped when they perform a surgical technique and are given feedback. Under test/evaluation conditions, the videos are assessed by more than one expert in the field. Patient interviews are taped and reviewed to assist in diagnosis, consult and education. (21, 55, 97-99)

This method is commonly used for assessment and feedback. The availability, low cost, and ease of use make it viable and popular. In addition, surgical programs have adopted the technology for diverse use such as consultation and managed care (100-102)

CD-ROM

The CD-ROM is, in essence, a data disk which has the capacity to store large amounts of data. It is used commonly for representation of text, 2-D images and short video and audio clips. (11, 103, 104) . CD-ROM is a static environment. When a large amount of information needs to be shared and distributed, a CD-ROM is often used. The utilization of CD-ROM technology is similar to Web technology, except it does not initiate discussions. (40) It also provides limited access to content. Thus, if instructors are concerned about unauthorized use of their material, then delivering course content on a CD-ROM provides some protection. It is a convenient portable medium with limited storage capacity, used to transport files and backups, as well as copyright course content. The use of CD-

ROM is declining due to advancements in other technologies such as the Web (25, 105).

Tele-health

Tele-health technology is understood to mean the integration of information and communication technology into the practices of protecting and promoting health (81). It is predominantly used for remote consultation, didactic teaching and health management. In many medical schools, Grand Rounds are broadcast using tele-health technology for continuing Medical Education.

Tele-health technology is also used for remote consultation and didactic teaching, particularly in rural communities. Radiology is one of the specialties that spearheaded many activities utilizing tele-health. The image transporting technology, such as the DICOM, lends itself well to

X-RAY transition and image transition for consulting. It is used to teach learners in remote areas. It also provides jurisdiction across borders and professional portability (106, 107).

The administration of tele-health requires organization of scheduling, classroom bookings and technical support at sites. Technically, bandwidth issues need to be addressed; further climate conditions have a potential of affecting transmission. Nonetheless, the technology has become the mainstay for remote access, particularly for teaching and consultation.

Personal Device Assistant (PDA)

A PDA is a small mobile hand-held device that provides computing and information storage and retrieval capabilities; it is used for therapeutic management, data storage, drug dosages and calculations. In the medical field, information of drug dosages, calculations, schedule and calendars are stored on PDAs. It is also used as a log to track clinical commitments by the students. Commercial vendors such as Lexi-Comp, Epocreties and One-Minute-Physician Consult all provide information for disease and therapeutic management and information is downloaded on to the PDA for immediate access (81, 108).

For example, Lexi-Comp Online provides up-to-date content in the following areas: drug information and interactions, laboratory and diagnostic tests, natural products, infectious diseases, and poisoning and toxicology. (URL: http://www.online.lexi.com) FIRSTConsult is another example where information for differential diagnoses, evaluation and management of medical conditions and patient education can be downloaded.

Virtual Reality

Virtual reality is the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height and depth. Virtual reality provides an interactive experience visually in full real-time motion with sound, tactile and other forms of feedback. (16) The simplest form of virtual reality is a 3-D image that can be explored interactively on a personal computer.

Virtual reality environments are used to simulate diagnostic and prognostic conditions. (109-114) Further, they are used to create clinical simulations. Examples from creating bleeding to anatomical movements can be found in the literature (115, 116) Fluid motion and breathing simulations are common representations in virtual reality (113, 115, 117, 118). These environments provide the students with the opportunity to learn and practice their skills with no risk, especially in a high-risk environment where patient safety is an issue.

Digital Imaging

Digital imaging is used to describe "photography" which involves capture, manipulation or exhibition of images using a computer or other digital device (119-122). Digitally-stored information takes up a fraction of the space consumed by paper. Large volumes of information can be accessed instantly over a network or Internet, or it can be made portable when published to CD-ROM or DVD. Digital manipulation of images play a key role in the development of multimedia presentations; digital images used in diagnosis and assessment are attached to patient charts; some are stored in databases supporting patient information. (74, 123-125).

Digital images are used in diagnosis and preoperative assessment. (126-128). As technology improves, the storage of these images and image quality will improve, providing a clearer accurate modeling of surgical possibilities (129, 130). Digital imaging emerges as a critical tool to assist in the efficient processing and analysis of large volume of data.

Robotics and Simulation

Current simulation technology is sufficiently realistic to emulate actual patient care. Patient simulation provides the ability to repeatedly practice a wide range of clinical scenarios (40, 131, 132) Because simulated clinical scenarios are completely replicable and highly standardized, it is much easier to review and evaluate performance, as well. Simulation experiences can be videotaped and reviewed by trainees to further facilitate learning (54, 115, 133, 134).

Animation is considered a representation of simulation, also. some researchers express it in the form of movement with PowerPoint slides, yet others achieve it through digital video combined with an expert system. (77, 135, 136) Animation can likewise be represented via mpeg files (109). The understanding of animation is that it represents movement of the anatomy. There is no definite formula for achieving it (42, 131, 137).

As society increasingly demands for less invasive procedures, the robotic systems might be one of the surgical choices for the future. Even though its cost is prohibitive, it is gaining popularity, particularly within laparoscopic surgery, cardiac surgery and neurosurgery; precision and accuracy are its virtues. Identified as having a steep learning curve, adequate training for the surgeons will be required, further adding to the cost (138-140)

Technology medium and usage

The literature surrounding technology-supported educational approaches predominantly discuss the utility of these tools and their effects on delivery of curriculum as related to cost, academic feedback, assessment, efficiency, management of time, attitudes, human behaviours and human resources. (9, 77, 141-143)

As seen in Table 1, technology that is most used are Web, video and digital technology. It is popularized because of the advances made within the technology, its cost effectiveness, ease of use, familiarity and access to the technology. Note (Table 2), Web technology is used in most medical disciplines, it provides access at any time making it an excellent communication tool for curricula. Digital imaging and video technology are also high in use. CD-ROMs, virtual reality and robotics are used less in comparison. This supports the information in Table 2.

Robotics, on the other hand, is less in use predominantly because of its cost and availability of applications specific for surgery. However, examples of the "da Vinci" robotic system for stenting, laparoscopic surgery, prostrate surgery, gastric bypass and mitral valve repair begin to appear in training (139, 144, 145). The use of CD-ROMs are becoming fast obsolete due both to their limitations of capacity and advances made in other medium.

Table 1: Technology, Medium and Usage

Technology	**Medium**	**Usage**
Web	Internet	High
Video	tapes, DVD	High
CD-ROM	Disks	Low
Tele-Health	satellite	Medium
Virtual Reality	Mannequin	Low
Digital imaging	Tapes, disk drives	High
Robotics	Mechanical device, da Vinci, neuron-arm	Low

Synthesized from literature (23, 25, 26, 51, 80, 86, 88, 111, 132, 139, 146-166)

Table 2: Disciplines Utilizing Technology in Teaching

Medical Discipline	**Web**	**CD-ROM**	**Video**	**Digital Imaging**	**Tele-Health**	**Simulation Virtual Reality and Robotics**	**WebCT Blackboard Illuminate**
Laparoscopic surgery	√		√	√			√
Surgery	√	√	√	√	√	√	√
Anatomy	√	√	√	√		√	√
Radiology	√			√	√		√
Pathology	√		√	√			√
Family Medicine	√	√	√	√			
Emergency Medicine	√		√		√	√	√
Psychiatry	√		√		√		

Medical disciplines that utilize technology for teaching

Video technology is used to the assess performance of residents, provide feedback and compare different learning models (151, 167, 168). Differences between genders and performance related issues are studied via video observations. Digital imaging is used for diagnosis and surgery (52, 169). Web and learning platforms are used for communication and dissemination of course content. Simulation is used to teach the skill; many of these simulators are designed and built at each site (117, 170).

Surgery

Video technology is used to assess performance of residents and to provide feedback. Digital imaging is used for diagnosis and surgery. (133, 171-173) Web technology is used for consultation, while learning platforms such as WebCT and Blackboard are used for dissemination of course content, assignments and communication (171, 174). Simulation and virtual environments are used for demonstrations (175, 176). Virtual reality training has been proposed as a method to both instruct surgical students and evaluate psychomotor components of minimally invasive surgery (177).

Anatomy

Technology-based animation is used to create "real life" learning models. Learning platforms are used for dissemination of course content in text format, communication and assignments. 2-D and 3-D images are used for teaching. (77, 178, 179). Since anatomy is considered a visual science by many, animated

PowerPoint presentations are used to teach. Video imaging is used for evaluation, while CD-ROM is used to disseminate course content. (180)

Radiology

3-D digital imaging is used for training in MRI and CT scans. Digital imaging is used in diagnosis and consultation in many urban sites (181-183). Further tele-health technology is used for rural education, diagnosis and consultation. Web and learning platforms are used for communication and dissemination of course content (182, 184).

Pathology

2-D and 3-D digitized slides are used to teach. (185, 186) Web technology is used to disseminate lectures, record attendance and log clinical rotations; these are all in text format (187).

Family Medicine

Computer simulation is used to teach Sigmoidoscopy (64, 112).

E-Learning tools with audio and video bytes are used in residency teaching. Learning platforms are used for dissemination of course content in text format and communication (188-190).

Emergency Medicine

In many studies, patient simulators create a "virtual learning" environment. (59, 191) Web technology is used to disseminate course content, and video technology is used to assess skills and provide feedback. Tele-health technology is used for remote education and consultation. (192, 193) Web and learning platforms are used for communication and dissemination of course content.

Psychiatry

Videotaping and digital editing provide compelling material that can be used for therapy for patients, teaching and professional presentation (194). Tele-health technology is used in distance psychiatry consultation, benefiting remote sites.

Surgical specialties that utilize technology

The expectation of a simulated environment is to create surgical educational experiences that are interactive teaching modules rich in basic science and clinical content (24, 61, 165, 195, 196). Current technology is sufficiently realistic to emulate surgical scenarios; it provides the ability to repeatedly practice a wide range of clinical procedures (165, 197, 198). Learning experiences can be videotaped, reviewed and assessed to further facilitate learning (86, 199).

Empirical evidence (Table 3) shows Web, video, and digital technology are used in many forms of surgery training, these technologies are more suited to support video clips of surgery, as communication tool to disseminate course material and for assessment. CD-ROM is not widely used because of limited capacity and diminishing popularity as a portable object; tele-health because of unstable satellite transmission, access to workstation, scheduling and image clarity. This information is congruent with information in Table 1 describing the technology medium and its usage in medical education.

Table 3: Principal technologies in surgical curricula

Surgical Specialties	**Web**	**CD ROM**	**Video**	**Digital Imaging**	**Tele-Health**	**Virtual Reality**	**Robotics**
Orthopaedic surgery	√		√	√		√	√
Laparoscopic surgery	√		√	√	√	√	√
Surgery	√	√	√	√	√	√	√
Cardiac surgery	√		√	√	√	√	√
Plastic surgery	√	√	√	√	√		
Neurosurgery	√		√	√	√	√	√
Urology and Obstetrics	√		√				

One example is presented for each specialty with additional empirical evidence.

Orthopaedic Surgery

An interactive computer tutorial to teach medical students and residents to perform knee-replacement surgery was designed and implemented at the University of California, San Francisco. The objective was to create a useful approach by preparing students and residents for operative cases using interactive computer simulations of surgery. The efficacy of this method was reported by Günter et al (200). Many such implementations based on reported success can be found in the literature (153, 201).

Laparoscopic Surgery

Aggrawal's studies have demonstrated the beneficial effect of training novice laparoscopic surgeons using a virtual reality (VR) simulator (23, 24, 151). The validated structured VR curriculum provides an evidence-based approach for a laparoscopic training program enabling trainees to familiarizes, train and be assessed on laparoscopic VR simulators (105, 151, 202).

Surgery

The purpose of Hsu et al's study(203) was to assess the existing model and to correlate performance on a simulator model of carotid artery stenting with previous endovascular experience. The study concluded that, the improvement in the novice group was greater than that in the advanced group, indicating that novices benefit from simulated training (204-206).

Cardio Thoracic Surgery

Since 1997, both the Cleveland Clinic and London Health Sciences Centre groups have utilized robotic assistance and more recently, demonstrated the efficacy of this technology in totally closed-chest, beating heart myocardial revascularization. This involved an orderly progression and the learning of new surgical skill sets (31, 139).

Plastic Surgery

St. Louis University (91), has developed multimedia plastic surgery teaching materials with full-fidelity digital sound, three-dimensional computer graphics, and "picture-in-picture" video capabilities. They claim that computer animation complements text explanation, image documentation, and graphic analysis techniques (207, 208).

Neuro Surgery

A virtual-reality surgical simulator for education is presented by Wang et al. The simulator incorporates the simulation of surgical prodding, pulling and cutting. Advanced features include the separation of the cut surfaces by retractors and post-cutting deformations. The experience of virtual surgery is enhanced by implementing 3D stereo-vision and the use of two hand-held force-feedback devices (51, 110, 209).

Urology and Gynaecology

Hubert et al state, (210) urinary diversion is a therapeutic option in quadriplegic patients with poor lower urinary tract conditions, but it is an invasive procedure.

As a less invasive solution, robotics is introduced. They claim, robotics brings control of surgical instruments, and allows surgeons to apply more easily their technical skill to the laparoscopic approach (211).

Global perspective

Britain

Virtual reality laparoscopic simulators are used to teach laparoscopic psychomotor skills at the Imperial College, London, UK and they support objective assessments of skills using dexterity-based and video analysis systems (23, 24, 202). The da Vinci system is used for cardiac surgery at the London Health Science Centre (31, 212)

Europe

Linkoping University, Sweden (213), report an increased use of surgical simulator systems for education and preoperative planning. A natural course of development of these systems was to incorporate patient specific anatomical models. Anatomical datasets are automated, or semi-automated to automatically segment the hip anatomy and generate models for a hip surgery.

The da Vinci system for close-chest cardiac surgery is performed in most of Europe; Italy (214), Germany (213), Romania (139) and Prague (215) all have adopted this method.

Japan

In the Department of Surgery, at Nihon University's Nerima Hikarigaoka Hospital, Tokyo, video-recorded surgical procedures are used to teach hepatectomy and rectal resection (216). The Department of Otolaryngology, at the Tokyo Metropolitan Ohtsuka Hospital, undertakes to perform microlaryngosurgery (96).

Taiwan

At the Chung Yuan Christian University, in Taiwan, an interactive virtual reality orthopaedic surgery simulator is used. The simulator allows surgeons to use various surgical instruments to operate on virtual rigid anatomic structures (116). It is considered a useful learning tool for effectively planning verification and rehearsal of operations.

Kuala Lumpur

Robotic surgery was introduced in the Department of Urology, Hospital Kuala Lumpur, in April 2004. A three-arm da Vinci robotic system supports a structured training program developed at Vattikuti Urology Institute (217).

Australia

At Queensland University and Griffith University, computer simulation of visual outcomes of wavefront-only corneal ablation is performed. The present simulation technique is used as a screening tool to predict patients' visual outcomes before the surgery (129).

America

Compared to the rest of the world America leads the way in implementation of technology supported simulated training in their surgical curricula. Many are developed and supported in the country by the technology industry. Commonly used are the da Vinci systems and in-house developments (18, 51, 218).

Local perspective

The NeuroArm, at the University of Calgary, is an MRI-compatible surgical robot. Designed to be controlled by a surgeon from a computer workstation, NeuroArm operates in conjunction with real-time MR imaging (219), still in test phase, its slated for human trials. There is currently no empirical evidence of its efficacy or safety.

The da Vinci system for robotics, virtual reality simulation and robotic surgery are functional at University of Toronto (General), University of Alberta (Royal Alexandra Hospital), Dalhousie and Ottawa Heart Institute (153, 220, 221).

Assessment in Surgery Using Technology

The educational objectives, learning experiences and assessment (test) procedures are the three primary components of an assessment instrument (222, 223). In medical education, assessments are primarily in the form of multiple choice exams (224), oral exams and the Objective Structures Clinical Exam (OSCE) (225-229). Royal college exams and Medical Council of Canada (MCC) exams predominantly use multiple-choice exam and oral exam formats to evaluate. Apart from direct observation of demonstrated skills by learners, the assessment of surgical skills in the classroom setting has become challenging (230, 231), since many surgical skill assessments focus on cognitive knowledge and skill demonstration (155, 230, 232-234). It has been shown that an increase in cognitive knowledge has a positive impact on skills. (15, 19, 174, 235, 236)

Cognitive Assessment

The increase in knowledge and its impact on skills is often measured in terms of cognitive knowledge. Multiple-choice exams (224), oral exams and OSCEs (225-229) are used for assessment. Web, video and tele-health technology is used for this purpose (50, 237-242).

In order to study the efficacy of an e-learning tool, valid assessment methods need to be established. As evidenced in the literature, there is no standardized method for assessment in surgery. Bench models and simulations are used to assess surgical skills; as well, the videotaping of skill performance for assessment purposes appears to be common (205, 234, 243-245).

Skill Assessment

There are no standardized methods in assessing surgical skills except to have set criteria of ability. The variation within the content, teaching objectives and learning environments overpower any standardization of assessment methods. The reliability of many of these assessment formats is often reported as case studies, or evaluation outcomes (246-248). Studies mainly report the alpha coefficient and inter-rater reliability measures (224, 241, 249). Even though the outcomes of these studies are not generalizable due to small sample size and variability inherent to the assessment objectives, claims are made of generalizability.

Methods of Assessment in Surgery Using Technology

Objective Structured Clinical Examination (OSCE)

Assessment of clinical skills in addition to factual knowledge has become part of the examination system in both undergraduate and postgraduate examination. The OCSE was first described by Harden et al. in 1975 (250). It was developed based on a need for improved evaluations of clinical performances in medical students. The OSCE format has timed stations through which students rotate while evaluators use an itemized checklist with specific grading criteria. It is graded using a standardized clinical scenario and a structured binary checklist. The observer completing the checklist can be an examiner who witnesses the performance of the student, a patient who is being practiced on by the student, or a combination of both. The advantage of this tool has been its ability to test the many dimensions of clinical competences such as physical examination, history taking, inter personal skills, problem solving, patient treatment and patient management. Adopted by many medical schools and the Medical Council of Canada as well as many specialty boards, this form of testing is accepted because of evidence of reliability and validity.

Multiple-Choice Exams

Typically, multiple choice exams have a stem explaining the question and four to five options from which to choose. They are used in testing cognitive knowledge as well as skills in text format. In surgical assessment, they are combined with an OSCE and/or demonstrated observation. An exam is designed with content validity and face validity constructs in order for it to be a reliable and valid instrument. Content validity is achieved by the experts in the field providing the questions, and face validity is achieved by pilot testing it with a targeted sample population.

Direct Observation

Direct observation is the ideal assessment in surgical skill evaluation. However, limitations such as human resources, availability of instructors, cost, access to operating rooms, policy governing patient care, scheduling and other variables make it difficult to execute, especially when the student population is large. Because of this, many assessment forms have adapted a combination of a varied methods, such as multiple-choice, video and OSCE. The combination model of assessment is a comprehensive process.

Video Assessment

Real-time assessment via direct observation for surgical assessment would be ideal. However, it is not feasible given the limited resources of instructor time and scheduling. An adopted method of evaluation is to videotape the performance of the students for assessment at a later time.

The literature surrounding technology-supported educational approaches predominantly discusses the utility of these tools and their effects on the delivery of curriculum related to cost, academic feedback, assessment, efficiency, management of time, attitudes, human behaviours and human resources.

Surgical Assessment and technology

There is widespread use of technology assisted skill assessment of technical proficiency in surgical education (101, 155, 251). For example, the acquisition of laparoscopic skills is difficult to assess; however, through the use of video and simulation, McNatt and Smith, (53) have shown that assessment of time, skill and outcome can be evaluated objectively. Simulations (virtual reality, mannequin) are high fidelity environments that provide best assessment outcomes.

Table 4 illustrates the medium used to assess skill, knowledge and attitude. Multiple choice questionnaires via the Web is a common form of assessment of knowledge and attitude. The information gathered is in text form and Web provides the ideal platform for this. Demonstrations using mannequin and oral exams vie tele-health platforms are also used to assess knowledge and attitude. Skill assessment is an observation of technique; video taping student performance is a common form of skill assessment as well using virtual reality (mannequin) where students are able to demonstrate their ability.

Table 4: Technologies used in assessment

Assessment	Web	Video	Virtual Reality (mannequin)	Digital and Tele-health
Skill		√	√	
Knowledge	√		√	√
Attitude	√			√

Learning Theories in Surgical Education

The following section provides theoretical background on contemporary and modern learning theories. An overall presentation of established learning theories originating from cognitive psychology, and the evolution of these theories that form the fundamental basis of current surgical education strategy, is provided. A limited number of these theories are identified as relevant to surgical education and are summarized as main theories of learning pertinent to medical and surgical education.

Introduction

Learning theories and learning models are vital topics in medical education, yet it is a difficult concept to define (252, 253). According to Klein, learning is a relatively permanent change in the probability of exhibiting a specific behaviour (254). This change in behavioural potential occurs as the result of experiences, either successful or unsuccessful. Scientific theory, on the other hand, can be described as a collection of related statements whose main function is to summarize and explain observations. Theories begin with certain assumptions partially based on observations. Tentative explanations are developed for the observations, leading to a hypothesis. The theorists proceed to gather data and test the validity of the hypothesis. If evidence supports the hypothesis, it becomes part of the theory or law (255, 256).

Skinner, Piaget, Bandura, Gagne, Miller and Tolman are all notables who have had an impact on theories of learning and their evolution. Four major divisions can be identified among them:

1) Behaviourist theories, 2) A transition period (Gestalist theories),

3) Cognitive theories, and 4) Social learning theories. Based on these foundational theories, many other theoretical structures have evolved over the last two decades (256, 257). The list is exhaustive, supporting the varied demands of cognition and behaviour in learning. Key elements of medical education are knowledge, skill and attitudes (253, 258-260), therefore learning theories supporting these elements become significant to surgical education.

Learning Theories Relevant to Surgical Education

Currently there is no dominant learning theory in surgical education; instead, models are the norm. All surgical learning models can be referenced to the foundational theories (Table 5).

Table 5: Foundational Theories

Theory	**Focus**	**Theorists**
Behaviourist Theories	Stimuli, response, reinforcement	Pavlov, Watson, Skinner, Thorndike
A transition period (Gestalt theories)	Stimuli, response, reinforcement, mediation, purpose, goals	Tolman, Hull, Hebb, Gibson
Cognitive Theories	Perception, decision making, problem solving, attention, memory, development	Piaget, Bruner , Bandura Flavell
Social Learning Theories	Information processing, coding, attitudes, learner-centred, modeling, observation	Bandura, Gagne, Miller

Among the modern theories, a limited number can be further identified as relevant to surgery. Many of them overlap in their theoretical position; however, they all provide a base for surgical learning models (Table 6).

Table 6: Modern theories pertinent to surgical education

Theory	**Focus**	**Theorists**
Adult learning theories (Cognitive theory)	Personal characteristics, situational characteristics, aging, developmental stages	Cross, Knowles, Rogers
Cognitive load theory	Schemas or combination of elements as cognitive structures of knowledge	Sweller
Cognitive flexibility theory	The theory is largely concerned with transfer of knowledge and skills beyond their initial learning situation	Spiro, Feltovitch, Coulson
Situated learning theory	Learning is a function of the activity, context and culture in which it occurs	Lave, Gibson, Wenger

A brief description is provided for each theory.

Behaviourist Theory

This theory deals with investigations of relationships among stimuli, responses, and the consequences of behaviour. Behaviourists concentrate on examining actual behaviour and the observable conditions that lead to the behaviour. (255,

257) Pavlov and Skinner are two of the prominent proponents of Behaviourism theories. Pavlov proposed classical conditioning (255, 261). One of the distinctive aspects of Skinner's theory is that information be presented in small steps and learners learn at their own pace with feedback from instructor.

Gestalt Period Theory

In 1912 a group of German psychologist identifying themselves as the Gestalt psychologists challenged the behaviourists' theories, and proposed their own. The basic argument advanced was that behaviour cannot be understood in terms of its parts that the whole (behaviour) is greater than the sum of parts. The theory proposes that learning results in the formation of memory traces. Hence, what is remembered is not always what was learned or perceived (255, 256).

Cognitive Theory

Focus is on central processing, problem solving, decision making, memory, perception and information processing. The cognitive orientation on learning theories further focus on human behaviour influenced by activities such as, thinking, feeling, intending, reasoning, remembering and evaluating. These are defined as cognitive process (254, 257).

Piaget's cognitive theory had a mix of empirical and non-empirical forms (262, 263). He further proposed that educational experiences must be built on cognitive structure. Burner's contribution to the theory explained various phenomena in perception, decision making, information processing, conceptualizing, and development (257, 264)

Social Learning Theory

Social learning theory integrates a variety of concepts that have traditionally been associated with separate positions. Thus, the integrated theory incorporates Pavlovian conditioning, Skinner conditioning and cognitive process. In addition, information processing theory has become a general theory of human cognition. Miller, Bandura, Gagne and Bruner are some of the prominent theorists to support the integrated vision.

The social learning theory of Bandura emphasizes the importance of observing and modeling the behaviours, attitudes, and emotional reactions of others. Bandura's theory improved upon the strictly behavioural interpretation of modeling (265, 266). Gagne described five major outcomes of learning in terms of domains: intellectual skills, verbal information, attitudes, motor skills, and cognitive strategies. While Gagne's theoretical framework covers all aspects of learning, the focus of the theory is on intellectual skills (267, 268).

Information Processing Theory

The phenomenon of chunking is introduced here by Miller, who provided two theoretical ideas that are fundamental to the information processing framework (269, 270). The first concept is "chunking" and deals with the capacity of short term memory. The concept of chunking and the limited capacity of short term memory became a basic element of all subsequent theories of memory. The second concept is TOTE (Test-Operate-Test-Exit) proposed by Miller, Galanter and Pribram; in a TOTE unit, a goal is tested to see if it has been achieved and if not, an operation is performed to achieve the goal; this cycle of test-operate is repeated until the goal is eventually achieved or abandoned (269, 270). The TOTE concept provided the basis of many subsequent theories of problem solving.

Adult Learning theory

There are many variations of adult learning theories. There is, however, debate on the actual number of theories. Overall, the theory of adult learning have two elements: 1) a process that creates change within the individual, and 2) a process to infuse change into an external environment (93, 271, 272). Knowles might well be considered the founding father of adult learning. Knowles sees an adult learner as self-directing, having a repertoire of experience, and being internally motivated to learn. Others focus on experience, critical reflection and development as key components of adult learning, additionally emphasize experience as an important factor in one's ability to create, retain and transfer knowledge (273).

Cognitive Load theory

Cognitive load theory, introduced by Sweller (274, 275), is an instructional theory describing learning structures in terms of involving long term memory. He states that information may only be stored in long term memory after first being attended to, and processed by, working memory. A combination of elements as cognitive structures make up an individual's knowledge, hence, whether information is stored in long-term memory or short-term memory affects knowledge and skill performance. The literature evidence supports the claim that cognitive load theory is best applied in the area of instructional design for cognitively complex or technically challenging material (274, 276).

Cognitive Flexibility Theory

Cognitive flexibility theory focuses on the nature of learning in complex and ill-structured domains (277, 278). The theory is largely concerned with transfer of knowledge and skills beyond their initial learning situation. The theory also asserts that effective learning is context-dependent; hence, instruction needs to be very specific. In addition, the theory emphasizes the importance of constructed knowledge; learners must be given an opportunity to develop their own representations of information in order to properly learn.

Situated Learning Theory

According to Lave (257, 279), learning normally occurs as a function of the activity, context and culture in which it occurs. Social interaction is a critical component of situated learning, where learners become involved in a "community of practice" which embodies certain beliefs and behaviours to be acquired. Other researchers have further developed the theory of situated learning. (280).

Current Learning Trends in Surgical Education

Implementing the findings of research and clinical practices assumes the evidence based model in surgical training (281-283). To achieve this goal, traditional, passive models of medical education in didactic lecture settings is abandoned; instead they are replaced by an active, clinically oriented, learner-centred approach.

The following are identified as learning models in surgical education

Evidence Based Medicine (EBM)

The term Evidence Based Medicine was coined by Guyatt originating from McMaster University (284). It is based on principles of sound evidence, the strength of inference the evidence permits and accepted practice guidelines. The strategy employed requires identification of the relevant question, search of the literature relating to the question, critical appraisal of the evidence and its applicability to the clinical situation (285-287).

Case Based Learning (CBL)

Most case based learning strategies (288) use cases as a means for testing one's understanding. One form of case based approach is to use the case as a concrete reference point for learning. Learning objectives and resources are presented along with the case. Another form is to present cases so that critical attributes are highlighted, thus emphasizing the content domain, but not engaging the learner in authentic problem solving in that domain (286, 289, 290). The process is detailed, specific, and focused on solutions(282).

Problem Based Learning (PBL)

Problem Based Learning is a pedagogical strategy of active learning and is currently practiced in more than 60 medical schools around the world. (272, 291, 292) Originating in McMaster University as a new approach to learning in Undergraduate medical school, it has since spread to the postgraduate curricula, and continuing Medical Education arena. PBL promotes student-centered education, self-directed learning and life-long learning (293, 294).

The defining characteristics of PBL are: Students work in small collaborative groups; learning is driven by challenging, open-ended problems and teachers take on the role as "facilitators" of learning. The main attributes of PBL include knowledge acquisition, critical thinking and problem solving. PBL is practiced in small groups of students accompanied by a facilitator. A realistic problem is presented and the students are expected to engage in gathering information about the problem, discuss the problem, define what they know, generate solutions and organize a self-directed learning plan. Generally, the solutions are presented and discussed in the following session and the educators facilitate the learning process by asking open-ended questions.

Experiential Learning

Learning from experience is the most fundamental and natural means of learning available to everyone. All too often, theories of learning, education and training are developed in isolation from one another. This is particularly true within the Medical Education curriculum, and more so within surgical training. According to Rogers (295), There is a growing consensus that experience forms the basis of all learning. In many medical schools, Kolb's experiential learning cycle approach is undertaken. Here, the term "learning" is described as attitudes and behaviours which determine knowledge acquisition (295, 296). Despite its many strengths, experiential learning is not immune to criticism; the main objection is the lack of direction attributed to experiential learning (297, 298).

Observational Learning

Observational learning is based primarily on the work of Bandura. He and his colleagues were able to demonstrate that learning could occur through the simple processes of observing someone else's activity. Bandura states: *"Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them what to do. Most human behaviour is learned observationally through modeling: from observing others one forms an idea of how new behaviours are performed, and on later occasions this coded information serves as a guide for action."* In surgical training the initial form of learning occurs by observing surgical procedures performed by experienced surgeons (266, 292, 299-301).

Relationship of Established Learning Theories and Current Trends

Table 7: Associated theories in surgery

Surgery Models	**Associated Theories**	**Focus**	**Applications in Surgery**
Evidence Based Medicine	Behaviourist theories Adult learning theory Cognitive theory Cognitive load theory Information processing theory Social learning theory	Reinforcement Organizing Purpose In-context Confirmation	Wet labs Morbidity and Mortality Journal clubs Grand rounds Academic half-day Lectures
Case Based Learning	Situated theory Social learning theory Cognitive theory	Activity, content, Culture Chunking	Academic half-day Grand rounds Morbidity and Mortality Lectures
Problem Based Learning	Cognitive theory Gestalt (period) theory Social learning theory Information processing theory Adult learning theory	Perceiving, Organizing, Decision making, Problem solving, Attention, Memory	Small group discussions Grand rounds Morbidity and Mortality
Surgery Models	**Associated Theories**	**Focus**	**Applications in Surgery**

Experiential Learning	Cognitive theory Cognitive load theory Cognitive Flex theory Behaviourist theory	Reinforcement Decision making Modeling Confirmation Practice	In operating room Bench model Wet labs
Observational Learning	Behaviourist theories Cognitive theory Social learning theory Information processing theory	Modeling, Chunking Repetition Perception	In operating room Wet labs Technology simulated environments

Measurement and Evaluation in Medical Education

Introduction

Constructing tests and interpreting test scores are a crucial part of formal education (302, 303). Theories such as the classical test theory (CTT), Item Response Theory (IRT), and Generalizability theory (GT) serve examiners well, since the assumptions of these models can be met by most test data, and therefore can be applied to a wide variety of test development and test score analysis (304). The two key psychometric properties that give credence to analysis of test data are reliability and validity. Model statistics such as standard error of measurement, Spearman-Brown formula, Cronbach's alpha coefficient, KR20, KR21, are used to estimate reliability of the test instruments. In terms of validity, construct validity, content validity and face validity are common forms of validity methods used to support the test objectives (305, 306).

As evidenced in the literature (307-309) surgical skill assessment methods pose a unique set of problems in constructing reliable and valid instruments for assessment (205, 246, 309, 310). The development of these test have inherent problems due to their environment (operating room), hospital policies, liabilities, human resources, cost, and time limits; often single tests are given on one occasion (54, 311-313). The credibility of the results depends on the reliability and validity measures of the test.

Test Theories

Classical Test Theory (CTT)

In CTT the observed score is expressed as the sum of true score component and an error component. The assumption is that each person has a true score that is assumed to be constant and a residual error component specific to that particular test score. The true score reflects systematic influences on test performances, i.e., individual examinee characteristics that are stable across repeated testing, and error reflects random, temporary, unstable characteristics. It must be assumed that the examinee's true score does not vary over some given set of possible measurements, therefore by definition such variation would be classified as error (302, 304). CTT is more closely associated with norm-referenced tests.

Observed score = True score + Error

Reliability in CTT can be achieved in parallel forms of test administration and test-retest methods. In parallel forms of test method, two interchangeable test forms are given to the same group of examinees with a suitable time interval between administrations, the observed correlation between scores on those two occasions is a parallel forms estimate of reliability. Reliability estimates should reflect the influence of all relevant sources of error (303).

In test-retest methods, reliability is estimated by repeated administration of the same test form. The correlation between repeated testing is referred to as test-retest estimate of reliability. The test-retest reliability is less satisfactory than the parallel forms of reliability; however, even though parallel forms reliability might be ideal it is difficult to obtain.

Reliability can be obtained using data from a single form on a single test. The problem of estimating test score reliability form a single test was addressed by Spearman and Brown who independently came up with the Spearman-Brown procedure. It involves dividing the test into two or more parts and estimating reliability from the consistency of performance across these parts. Alternative internal-consistency estimation procedures developed require less stringent assumptions. From the point of feasibility, single tests administered on a single occasion are favoured and practiced in most cases. As evidenced in the literature, it is particularly true in the surgical skill assessment methods (314-316)

Generalizability Theory could be considered as an evolution of CTT. In the 1970s CTT began to fall into the overarching model of GT (302, 304). The terminology and statistical results of CTT are still widely used. Even though recent refinements have rarely contradicted the results, CTT still remains an important part of Study 1n testing, both in its own right and as the source of important concept and method.

Item Response Theory (IRT)

Item Response Theory has been used to enhance the educational measurement process in a wide range of settings, including item generation, test construction, differential item function, computerized adoptive testing, scaling, equalling, standard setting and test scoring (317). It is a family of statistical models used to analyze test item data (304, 305, 318). IRT provides a unified statistical process for estimating stable characteristics of items and examinees and defining how these characteristics interact in describing item and test performances.

In comparison to Classical Test Theory, IRT makes stronger assumptions, these assumptions are related to the probability that an examinee with a particular ability level will produce a particular response to a particular item. IRT models relate item scores to examinee ability levels and item parameters using nonlinear functions. IRT produces a wider range of detailed predictions, both unconditional (for groups of examinees) and conditional (for examinees at a particular ability level). The major focus of IRT is on individual items, their unique characteristics and their independent contribution to test, it lends itself to criterion-referenced testing environments. In summarizing IRT models, each model employees a particular mathematical expression to represent the probability that a person will get an item right as a function of their ability and the characteristic of the item, therefore predictions can be made of how a person with a particular ability level will respond to any item or a set of similar items that fit the model. Individual performances are scrutinized in surgical assessment, the IRT model lends itself well as the theoretical model for test construction in surgery (97, 319, 320).

The inference from a person's observed item performance to his or her ability level is analogous to an inference from an observed score to an inverse score. Simple generalization relies on sampling models to warrant generalization to a universe score. IRT warrants inference from item performance to an ability level on overall scale. Both CTT and IRT involve inference from observed performances on some item to claims about overall performance on a universe of possible test items.

Generalizability Theory (GT) provides a framework for conceptualizing, investigating, and designing reliable observations. GT was originally introduced by Cronbach and colleagues in response to limitations of CTT (321-323).

Reliability

Reliability analysis allows one to study the properties of measurement scales and the items that make them up; the purpose of reliability is to quantify the precision of test scores and other measurements. The definition, quantification and reporting of reliability must each begin with the consideration of intended test uses and interpretations. Validity on the other hand, is centrally concerned with attributes and test measures, whereas, reliability places more emphasis on statistical measures (304, 306, 317). The reliability analysis procedure calculates a number of commonly used measures of test reliability and provides information about the relationships between individual items in the test. Using reliability analysis, one can determine the extent to which the items in a questionnaire are related to each other, can get an overall index of the repeatability or internal consistency of the test as a whole, and can identify problem items that should be excluded from the test (324, 325).

Statistical frameworks have been developed for analyzing the reliability of test scores; notable examples are Classical Test Theory and Generalizability Theory. Reliability can also be developed in the context of Item Response Theory. Both CTT and GT offer data collection designs and statistical models to estimate the Standard Error of Measurement (SEM) (302, 326). The SEM is the number expressed in the same units as the corresponding test score and indicates the accuracy with which a single score approximates the expected value of the possible score for the same examinee, thus the test score's precision is traditionally expressed using a reliability coefficient (322). The reliability coefficient is defined not for a single score, but test scores obtained for a sample from an examinee population. It is a statistic ranging from zero to one.

Models commonly used in reliability assessment are (302, 318):

- Cronbach's Alpha: Model of internal consistency, based on the average inter-item correlation.
- Test-retest: Applied more than once, assesses the correlation between the test for reliability.
- Split-half: Splits the scale into two parts and examines the correlation between the parts.
- Parallel: Model assumes all items have equal variances and equal error variances across replications.

- Strict parallel: This model makes the assumptions of the parallel model and also assumes equal means across items.

Validity

Validity is said to be complex, yet is an ever important component in medical education research. The "Standards for Educational and Psychological Testing", published in 1985, was the result of the work done by the joint committee of the American Education Research Association, the America Psychological Association, and the National Council on Measurement in Education. They outline content validity, construct validity and criterion validity as the three forms of validity that ought to be emphasized (54, 319, 327). As tests cannot always be neatly categorized in this manner, extension to these basic three forms is incorporated in the measure of validity.

A typical question to ask of validity is "Are we measuring what we think we are measuring?" In the case of assessment, validity means the degree to which a measurement instrument truly measures what it is intended to measure. The types of validity addressed in the medical education literature are mainly content validity, construct validity and criterion validity. Decrement validity, predictive validity, convergent validity, face validity and concurrent validity are also used to validate an assessment instrument. The main methods of studying validity are through Pearson product moment correlation, factor analysis, and regression analysis.

Forms of validity

Construct validity is considered one of the most significant advances of modern measurement theory and practices. Construct validity reflects the extent to which a test is successful in measuring a hypothetical construct. The assessment of variance becomes the focus. It seeks to explain individual difference in test scores. According to Cronbach there are 3 parts to construct validation: 1) suggesting which constructs possibly account for test performance, 2) deriving hypothesis from the theory involving the construct, and 3) testing the hypothesized relationships empirically (328). The significant aspects of construct validity are that it addresses theory, theoretical constructs and scientific empirical inquiry. When a measurement instrument is expressed in terms of multiple items, factor analysis is used for construct validation (114, 157, 329, 330).

Content validity is the representativeness or sampling adequacy of the content which is predominantly based on rational analysis. The assessment instrument should accurately represent the skills or characteristics it is designed to measure; expressed differently, it should draw an inference from test scores to a large domain of items similar to those on the test. Content validity must be built into the test beforehand, ideally by experts in the field of the subject matter. There is a plethora of examples in medical education literature that establish content validity in measuring instruments (249, 331-333)

Face validity refers to what the test appears to measure at face value. There is no quantification of judgment or any index of agreement computed between experts in face validity (236, 334).

Criterion validity can be represented by a statistic such as the correlation coefficient. Criterion validity is a measure of how well one variable or set of variables predicts an outcome, based on information from other variables. These variables are often represented as “intermediate” and “ultimate” criteria. While the relationship between a set of test scores and a set of criterion scores can be expressed with statistics, it is rare to base criterion validation on a single score. Often, correlation between tests and criterion scores for several samples of subjects are sought.

Predictive validity examines the degree to which a measure accurately predicts expected outcomes. This is a sub-class of the criterion-related validity where future performances of the criteria are predicted; i.e., one predicts the existence or non-existence of the relationship. The predictive validity of a test is always in relation to a specific criterion. In general the higher the validity coefficient is, the better the prediction. Violato and Donnon (335) used it to investigate the predictive validity of MCAT for clinical reasoning skills upon completion of medical school.

Concurrent validity Is also considered a sub-class of criterion validity. This method is of interest when a particular test is intended as a more efficient way of testing compared to an existing test. In other words it is used to describe the relationship between an old established test and a new test. The new test could be considered to have concurrent validity if it correlates with the old established test. Essential to this approach to validation is that there must be a reasonably valid and reliable criterion with which scores on instruments can be compared (305)

Discriminant validity is said to occur when instruments that supposedly measure the different items have a low correlation, often times it is used to establish construct validity.

Convergent validity means that evidence gathered from different source all indicate the same meaning of the construct. They converge towards the same conclusion.

Summary of Literature Review

Technology in medical education is prevalent in all specialities and sub-specialities of medicine. In surgical training technologies such as Web, video, CD-ROM, virtual reality, digital imaging, robotics and simulation are used to meet specific teaching objectives. Due to factors such as cost, availability, access, technical advances some are utilized more than others. Web, video and digital imaging rate high in usage, in teaching as well as surgical skill assessment. Knowledge and attitudes are assessed via Web based multiple choice questionnaires and evaluations. Empirical evidence indicates all surgical sub-specialities (orthopaedic, laparoscopic, general, cardio thoraiac, vascular, plastic, neurology and gynaecology) use Web and various other available medium to support their surgical training.

Teaching models in surgical training are based on foundational learning theories such as behaviourist theory, Gestalt theory, cognitive theory, and social learning theory, as well as such modern theories as adult learning, cognitive load, cognitive flexibility, and situated learning theories. The learning models in surgical education are Evidence Based Medicine (EBM), Case Based Learning (CBL), Problem Based Learning (PBL), experiential learning, and observational learning. As evidenced surgical training methods are based on foundational and modern learning theories, and modern learning models. These theories and models in combination with technology are effectively used to meet specific learning objectives within each surgical speciality.

Assessment in the form of Multiple Choice Questions (MCQ) is common, particularly in testing cognitive knowledge and attitudes in surgery. In order to assess the students accurately MCQs need to be valid and reliable instruments. The purpose of reliability is to quantify the precision of the test scores and other measurements. Validity is centrally concerned with attributes and test measures. MCQs that are constructed based on classical test theories or item response theory are reliable and valid test instruments for assessment.

Advantages of technology-supported learning

- Anytime, anyplace access to curricular materials and learning resources
- Capacity for use of multiple media types
- Greater control over pacing and sequencing of content delivery
- Opportunity for content review, practice and reinforcement
- Accommodation of varied learning styles and preferences
- Capacity to receive standardized curriculum regardless of physical location

Research Question:

"Can an electronic Knowledge Model (e-KM) of a surgical procedure enhance knowledge acquisition among learners?"

Sub-set of Research Questions:

- Do the students repeat watching elements of e-KM more than once?

- Is there a difference between the groups (e-KM and Instructor) with respect to knowledge acquisition?
- Does video access time, pearls access time (teaching points) and illustration access time have an impact on total test scores?
- Does the number of video clicks have an impact on the total test scores?

CHAPTER 3: METHODS

Overview

In recent years, the development of technology based educational tools has undergone a methodological change. One developmental approach to these tools has been the Usability Engineering approach to the design phase, the objective being to improve the design and dissemination of educational content to achieve maximum learning (336-338). Usability Engineering methods are considered an interdisciplinary approach to system design; their basis is derived from human-machine learning, computer science and systems engineering. Usability Engineering has specific attributes such as learnability, efficiency, memorability, errors and satisfaction; a successful system design would incorporate these attributes into their design process. As the term implies, usability is the assessment of how well a system accommodates end-user needs. Therefore, in order to achieve maximum efficacy in developing e-KM, usability criteria were employed, although these are not formally identified in theories of learning and medical education.

- *Learnability* is a common term used in engineering and computer machine learning disciplines to describe the ease of learning a system; i.e., a user should be able to rapidly get started and get work done(35, 338).

- *Efficiency* is when the use of the system is learned and productivity is high.

- *Memorability* is a term used in machine learning to describe the ability to remember a system. Ideally, a system should be easy enough to remember so that a casual user does not have to re-learn after a short period of absence (35, 337, 338).

- *Error* is defined as: the system must have low error rates, so that few errors are made by users, and recovery from the errors should be fast and easy.

- *Satisfaction* is said to be: the system should be pleasant to use, should be "user friendly" and should provide an overall sense of satisfaction on the part of the user.

In the development of e-KM, Usability Engineering attributes were employed. In order to study the efficacy of e-KM, two assessment instruments were designed adhering to pedagogical criteria. Assessment instruments are a form of measurement, according to Hopkins (306), measurement involves a process by which things are differentiated and described. It is not limited to the use of highly developed and refined instruments. Any differentiation among members of a class of things that is expressed numerically illustrates a process of measurement. The two most important qualities of a good measurement instrument are validity and reliability (37, 48,,50). For the purpose of this study, content validity, face validity and construct validity was used to determine the validity of the assessment/test instrument. Cronbach's alpha was used as a reliability indicator.

Study Design 1

Participants: 56 undergraduate second year (pre-clinical class of 2009) medical students were randomly assigned into two groups. Assignment was done by randomly assigning numbers (1 and 2) to the participants and grouping them accordingly.

Procedure: Group 1 received e-KM Web application. Group two received instruction from a human teacher. The standardized surgical procedure of removing a sebaceous cyst was demonstrated for both groups, after which they were asked to participate in the same test/assessment specifically designed for the purpose of assessing knowledge acquisition. Both groups were assessed with the identical (test) tool. A maximum time of 2 hours was allocated for the entire activity. Group 1 utilizes e-KM to access a real-time video clip, several pearls of relevant information and clearly articulated illustrations all of which they could access multiple times. Group 2 had a surgeon instructor present a PowerPoint presentation for approximately 20 minutes describing the surgical procedure of removing and providing relevant information about the procedure, following which the students were assessed.

Study Design 2

Participants: 62 undergraduate second year (pre-clinical class of 2010) medical students participated. Study design 2 was similar to Study 1, except the assessment instrument was modified to increase the MCQs to 35 in order to address professionalism, clinician behaviour and informed consent. As in Study 1, randomization was done by assigning numbers 1 and 2 to the participants and grouping them accordingly.

Procedure: Group 1 received the e-KM Web application. Group 2 received instruction from the surgeon teacher. The standardized surgical procedure of removing a sebaceous cyst was demonstrated to both groups, following which they were asked to participate in the test/assessment specifically designed for the purpose of assessing knowledge acquisition. A maximum time of 2 hours was allocated for the study.

The research was conducted in three phases.

- Phase 1 was the design of e-KM and the Web application used to deploy e-KM.
- Phase 2 was the construction of the assessment (test) instrument specific to e-KM.
- Phase 3 was data collection comprising Study 1 and Study 2 over a two year period.

The e-KM group accessed the instruction via a unique URL giving access to the Web application. *(http://www.hilab.med.ualberta.ca)*

Design of Assessment Instrument

The content experts formulated 35 MCQs based on the learning objectives and the table of specification for Study 1 and 40 questions for Study 2. It was further narrowed downed to 30 MCQs for Study 1 and 35 MCQs for Study 2. The experts participated in the assessment tool to assess the time required to complete the test and a decision was made to allocate 30-45 minutes.

Rational

Sebaceous cyst is a common medical presentation, often referred to as *"lumps and bumps."* The training in the removal of a sebaceous cyst is important as it appears to be a common occurrence, often requiring surgical intervention to remove it. It was identified by the family practice preceptors as one of the top three procedural skills all students ought to know and be comfortable with the treatment of it (339).

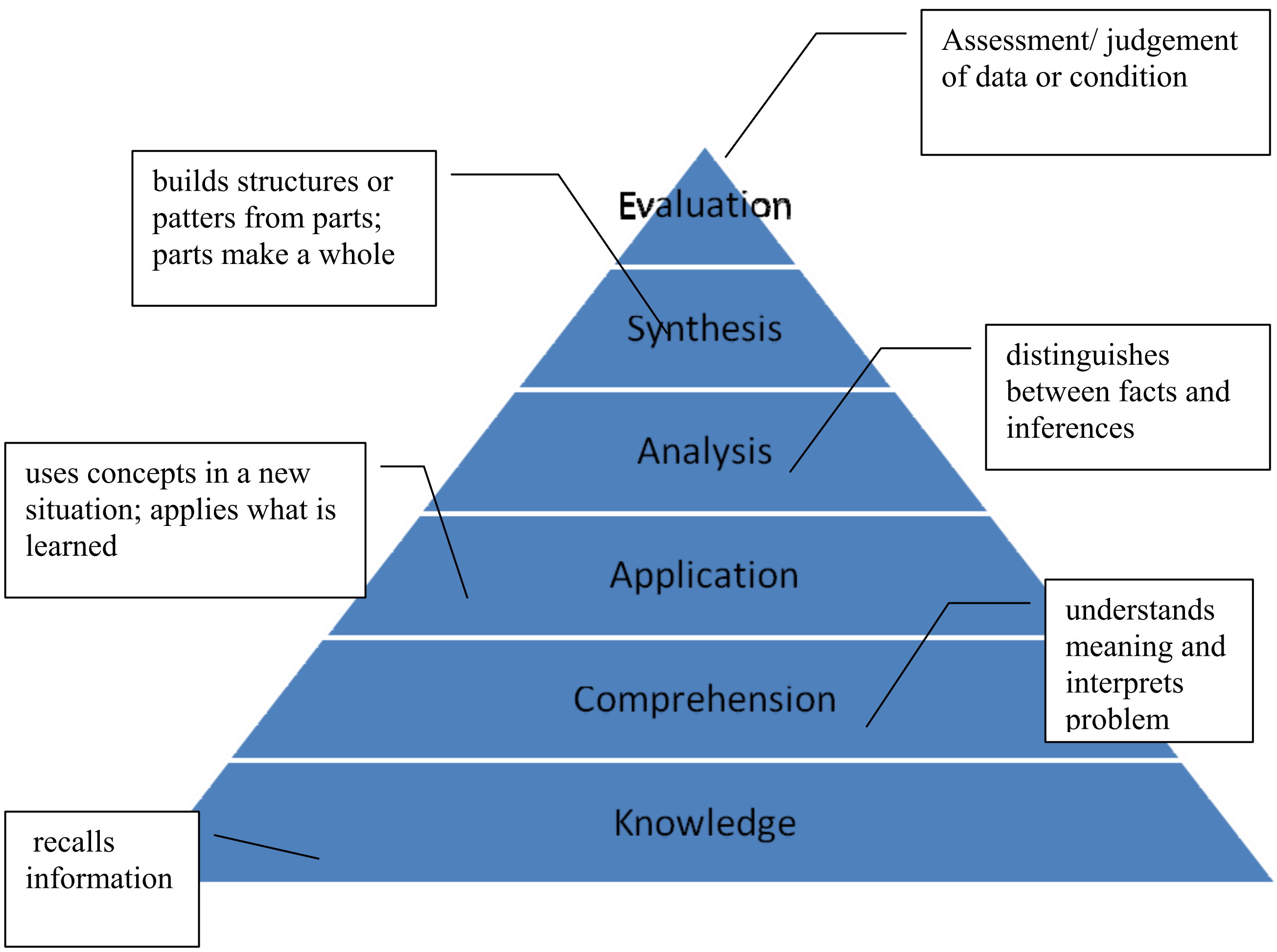
Main Goal

The learner must have a cognitive understanding of the physiology and procedural treatment for the cyst. Although sebaceous cysts are usually found on the face, neck, and trunk, they occur in the vaginal area or other parts of the genitalia of both women and men. Learners must be able to differentiate a sebaceous cyst from other forms of cyst such as herpes. They are generally mobile masses that can consist of fibrous tissues and fluids, from a fatty (sebaceous), substance that resembles cottage cheese, to a somewhat viscous, serosanguinous fluid (containing purulent and bloody material). The nature of the contents of a sebaceous cyst, and of its surrounding capsule, will be determined by whether the cyst has ever been infected. At surgery, a cyst can usually be excised in its entirety; poor surgical technique or previous infection leading to scarring and tethering of the cyst to the surrounding tissue may lead to rupture during excision and removal. A completely removed cyst will not recur; however, though if the patient has a predisposition to cyst formation, further cysts may develop in the same general area.

The nature of the simulation would be a real-time video clip of the elected procedure, with narration by the physician. The instructional objectives would focus on diagnosis, anatomy, instruments, sterile field, dissection, incision and complications. Knowledge of the procedural treatment would include differential diagnosis, the preparation of a surgical tray, and use of anaesthetic, appropriate incision, assessment of *"sack",* and removal, or excising of the cyst.

The theoretical framework of taxonomy is that statements of educational objectives can be arranged in a hierarchy from less to more complex. The largest proportion of educational objectives falls into the cognitive domain. The table of specification is designed using Bloom’s Taxonomy (340). The three major categories - knowledge, skills and attitudes - are the basis of taxonomy of learning behaviors; after the training session, the learner should have acquired new skills, knowledge, and/or attitudes. The three domains are divided into subdivisions, starting from the simplest behavior to the most complex. The divisions outlined are not absolutes and there are other systems or hierarchies that have been devised in the educational and training world. Bloom's taxonomy is easily understood and is the most widely applied model in use today; hence it is used in the table of specification for cognitive assessment.

Figure 1: Bloom's Taxonomy of cognitive objectives



Bloom's Taxonomy (1956)

Learning objectives for Study 1

Table 8: Learning objective with corresponding content strata for Study 1

Content Strata	**Learning Objectives**
Diagnosis	Differential diagnosis (sebaceous cyst, tumour, herpes)
Sterile field and instrument	Needle driver, suture, iodine, wrap, scalpel, antiseptic
Anaesthetics	Toxicity, dosage
Incision	Plane of dissection, assessment of depth
Complications	Rupture, Infection, bleeding, wound closure
Follow up	Suturing, removal of sutures, wound healing, oozing

Table 9: Table of specification for Study 1

Content Strata	**Cognitive Level (Bloom's Taxonomy)**			**Total**
	Knowledge	**Comprehension**	**Application**	
Diagnosis	4	3	3	10
Instruments, Anaesthetics	4	2	2	8
Incision, Dissection	2	2	2	6
Complication and follow up	2	2	2	6
Total				30

Learning objectives for Study 2

Table 10: Learning objectives with corresponding content strata for Study 2

Content Strata	**Learning Objectives**
Diagnosis	Differential diagnosis (sebaceous cyst, tumour, herpes)
Sterile field and instrument	Needle driver, suture, iodine, wrap, scalpel, antiseptic
Anaesthetics	Toxicity, dosage
Incision	Plane of dissection, assessment of depth
Complications	Rupture, Infection, bleeding, wound closure
Follow up	Suturing, removal of sutures, wound healing, oozing
Professionalism	Appropriate behaviours in a clinic

Table 11: Table of specification for Study 2

Content Strata	**Cognitive Level (Bloom's Taxonomy)**			**Total**
	Knowledge	**Comprehension**	**Application**	
Diagnosis	4	3	3	10
Instruments Anaesthetics	4	2	2	8
Incision, Dissection	2	2	2	6
Complication and follow-up	2	2	2	6
Professionalism			1	1
Patient confidentially	1		1	2
Clinician Behaviour	1		1	2
Total				**35**

Computer Design and Application

Design of e-KM

The e-KM Web application is illustrated as Home page (Figure 2), Case History (Figure 3), Video byte of 12 minutes demonstrating the procedure, "*pearls*" (Figure 4), and 10 illustrations (Figure 5, and Figure 6). Following which the students were asked to participate in the assessment/test tool, and the user satisfaction measurement instrument.

The sebaceous cyst application is designed with Macromedia Flash front end. It contains various screens of text information, 2-D images and video byte. The original video was modified using Window's Movie Maker version 2.1 and Adobe Premiere Pro. The Audio Video Interleave (.avi) was then converted into Flash Video (.flv) using Macromedia Flash 8 Video Encoder.

Database

The student responses data was stored into Microsoft Access database. The database was converted to Excel and SPSS files for statistical analysis.

Figure 2: Home page

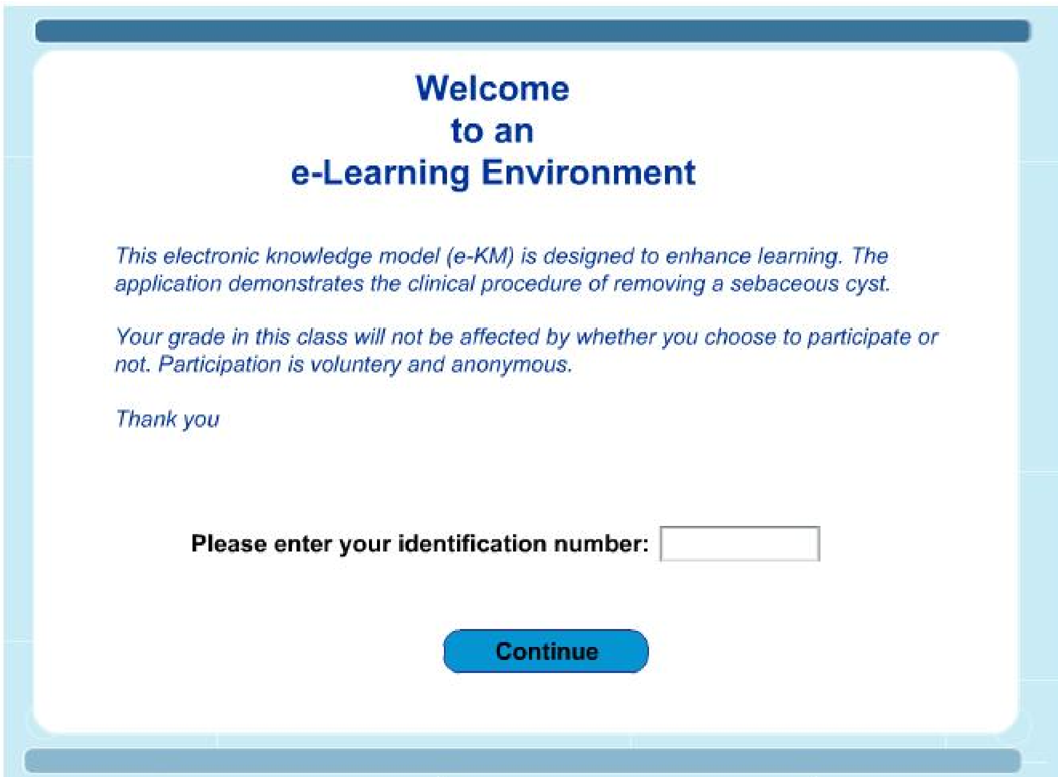


Figure 3: Case history

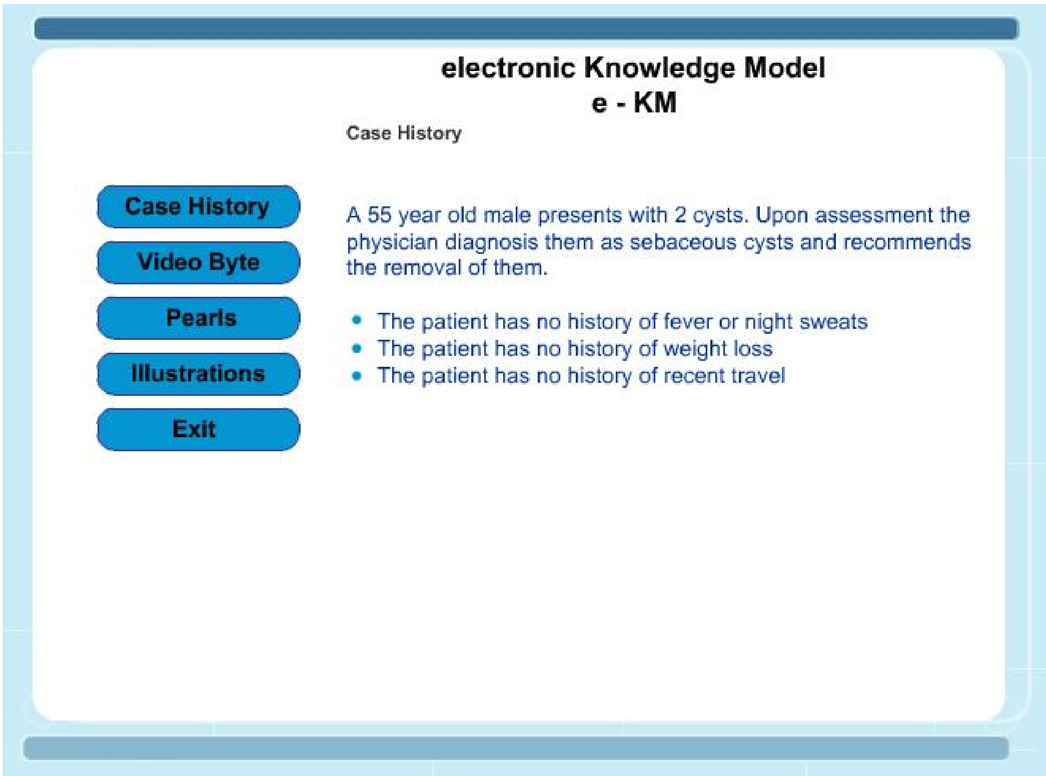


Figure 4: Pearls

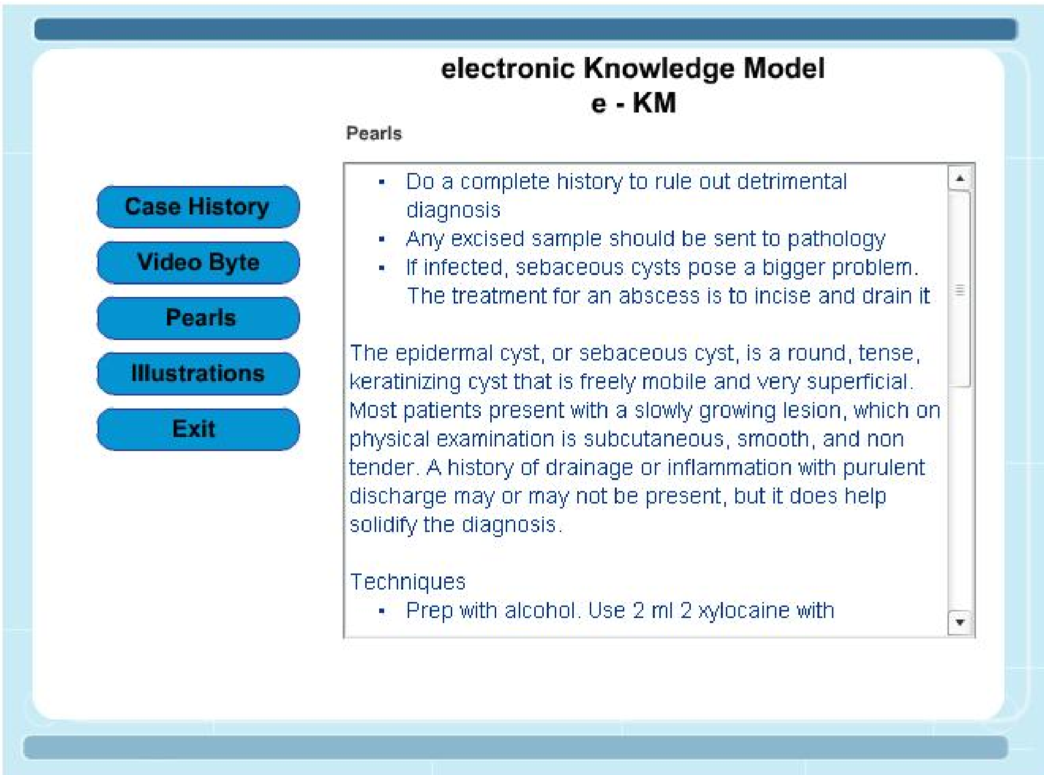


Figure 5: Illustrations of Instruments

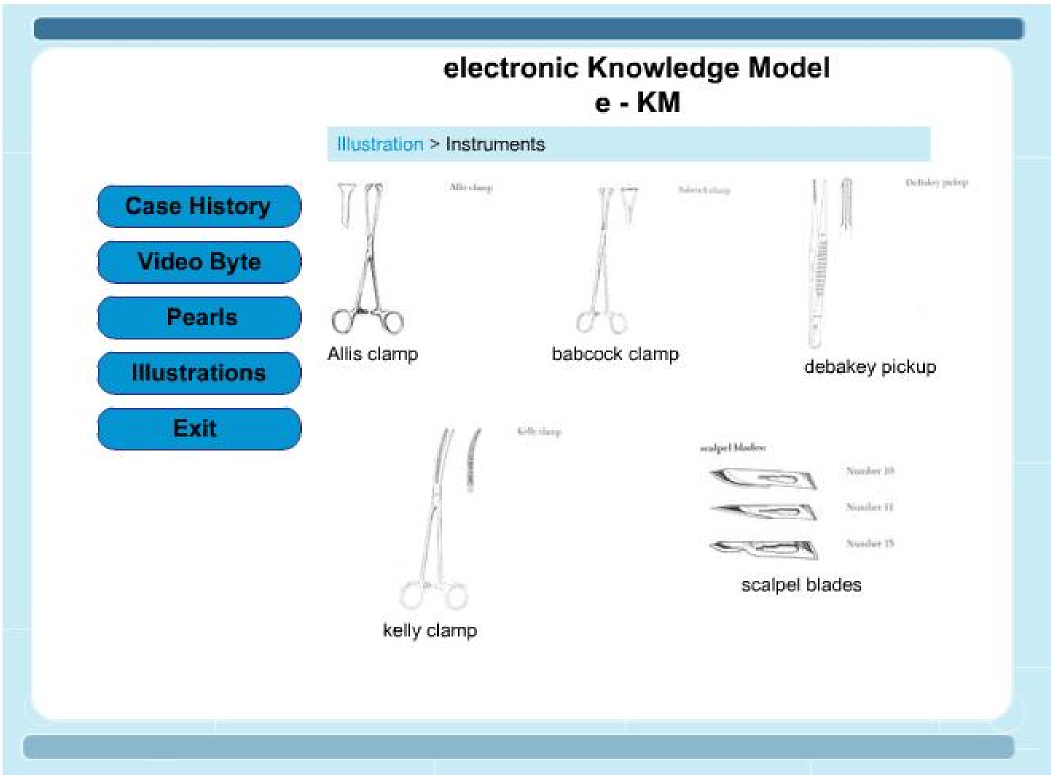
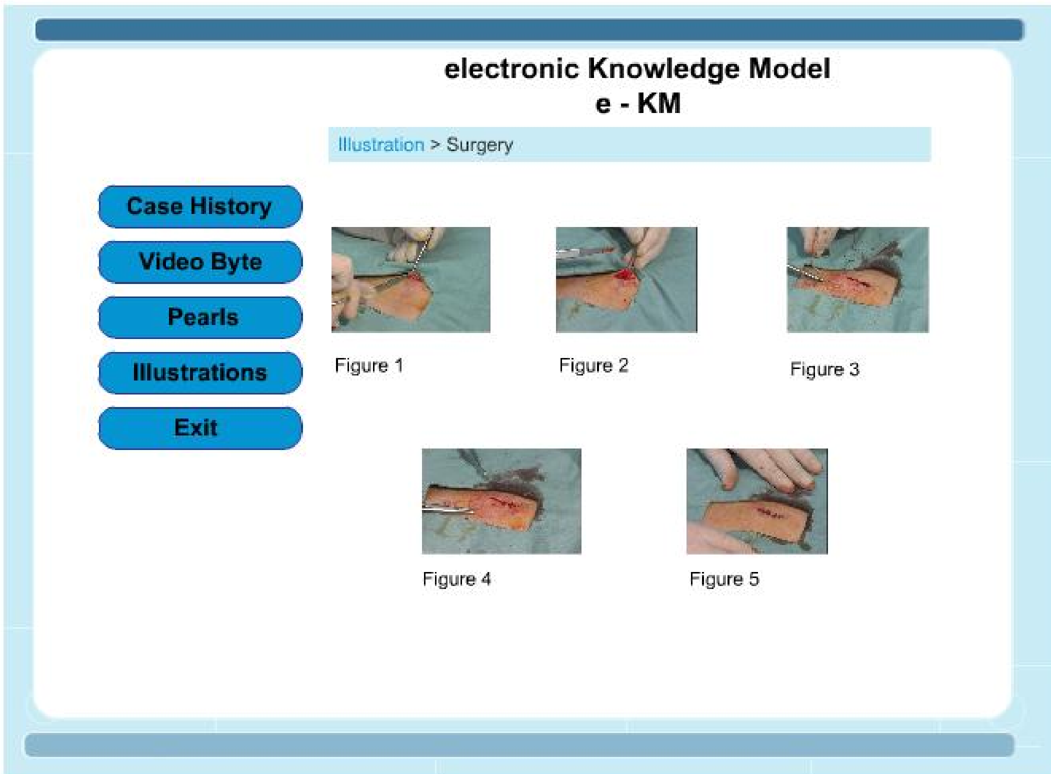


Figure 6: Illustrations of Surgical Procedures



Data Collection

Permission

Permission was acquired from the Associate Dean for Undergraduate medical education at the University of Alberta for student participation. It was made clear there would be no coercion, all data collected would be anonymous, and participation in the study was voluntary. Further permission was required from the instructor for class announcements. All participating students were provided with a voluntary consent form. Consent was obtained from the physician and patient who participated in the surgical procedure of cyst removal. (See Appendix A for verbal announcement, student consent, physician consent, patient consent).

Ethics

Ethics approval was obtained from the Research Ethics board at the Faculty of Medicine and Dentistry at the University of Alberta.

Process

The Web application e-KM for cyst removal was designed and a unique URL www.hilab.med.ualberta.ca was set-up for the study. e-KM had the capability of tracking the number of times the video byte, illustrations and pearls were accessed by each participant. The application also tracked the time spent on the video byte, pearls and illustrations. The tracking responses was automatically collected into a database for analysis. Paper and pencil format was used to collect the responses for the assessment/test. The distinction between the groups was made by the colour coded response sheets. Group 1(e-KM) was given pink paper, and group 2 (human instructor) was given orange paper. Second year (pre-clinical) medical student volunteers at the University of Alberta participated in the study. A class announcement was made by the instructor, the volunteer participants were then randomly assigned to two groups. Group 1 was escorted to the computer lab where they were allocated a computer ID number to gain access to e-KM. This unique number was also recorded in their assessment/test, as way of identifying the e-KM user and their test responses. Assessment/test responses were recorded on colour coded paper. Group 2 stayed in the room and had the classroom instructor. The instructor presented the case of cyst removal, discussed the diagnosis, and described the surgical procedure. He also gave a PowerPoint presentation for approximately 15-20 minutes. Following this the students were asked to participate in the assessment/test.

CHAPTER 4: RESULTS

Overview

Two experimental studies were conducted at the Faculty of Medicine and Dentistry at University of Alberta from 2007-2008. For both studies, undergraduate second year (pre-clinical) medical students were recruited to participate. Both Study designs were similar except for the test instrument. Item analysis of the Study 1 test instrument indicated the need for revision of the instrument, prompting revision of questions 5, 7, 16 and 28 (Appendix B). Additionally, the MCQs were increased by 5 questions to test professionalism, informed consent and physician behaviour in Study 2.

Participants: In a class of 125 medical students each, 56 participated, accounting for 45% class participation in Study 1 and 62 participated in Study 2 (a 50% class participation), accounting for a cumulative sample size of 118. (see Table 12)

Table 12: Sample size

	E-KM GROUP	SURGEON GROUP	TOTAL SAMPLE SIZE
STUDY 1	31	25	56
STUDY 2	32	30	62
TOTAL SAMPLE SIZE	63	55	118

Randomization was done assigning numbers (1 and 2) to the participants. Group 1 received e-KM on the Web. Group 2 received instruction from a human teacher (surgeon). Both groups received the identical test instrument for assessment. A maximum time of 2 hours was allocated for the entire activity. The e-KM group accessed the instruction via a unique URL on the Web (http://www.hilab.med.ualberta.ca). Group 2 had a surgeon instructor present a PowerPoint presentation for approximately 20 minutes describing the surgical procedure of removing a cyst and providing relevant information about the procedure. Following both activities the students were asked to participate in the assessment. Data entry for the tests scores were done and statistical package SPSS was used for data analysis.

The research was conducted in three phases: the design of e-KM; the construction of assessment (test) instrument and data collection over a two year period by way of Studies 1 and 11.

Data was then analyzed to answer the overarching research question "Can an electronic Knowledge Model (e-KM) of a surgical procedure enhance knowledge acquisition among learners?" and the sub-set of questions

- Do the students repeat watching elements of e-KM more than once?
- Is there a difference between the groups(e-KM and Instructor) with respect to knowledge acquisition?
- Does video access time, pearls access time (teaching points) and illustration access time have an impact on total test scores?
- Does the number of video clicks have an impact on the total test scores?

Study 1

Descriptive Statistics

Exploratory analysis was undertaken to explore normality of the data. The Kolmogorov-Smirnov and Shapiro-Wilk statistics indicate the data are normally distributed. Normality is further illustrated by histogram (Figure 8), therefore analysis of variance (ANOVA), Pearson's correlation and regression were appropriate to use as statistical analyses for the data.

Figure 7: Histogram for Normality

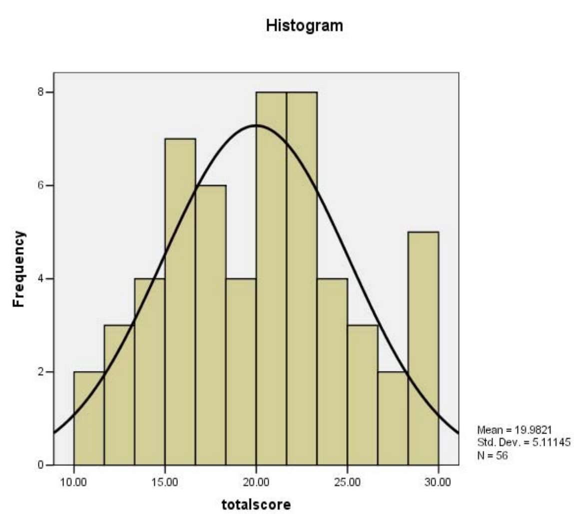


Table 13: Descriptive statistics for Study 1

Group	N	Mean	Std. Deviation	Variance
e-KM	31	19.25	5.99	35.99
Surgeon	25	20.88	3.65	13.36
Total	56	19.98	5.11	

Descriptive statistical analysis (Table 13) yields mean value of 19.25 for e-KM and mean value for surgeon as 20.88. The variance for e-KM is 35.99. and variance for surgeon is 13.36. There is no significant difference ($p>0.05$) between the surgeon and e-KM group (Table 14).

Table 14: ANOVA for Study 1.

Total score	Sum of squares	df	Mean Square	F	Sig
Between Groups	36.41	1	36.01	1.40	0.24
Within groups	1400.57	54	25.93		
Total	1436.98	55			

Table of specification for Study 1 and Study 2 (Tables 9, 11 respectively) presents the content strata and cognitive level for assessment using Bloom's Taxonomy. There are 3 components knowledge, comprehensions, and application and the 30 MCQs covered these. This can be modeled into the ANOVA and have a 2×3 factorial design. The 2 levels of factor 1 are instructor vs. e-KM and the 3 levels of factor 2 are knowledge, comprehension and application MCQs. The interaction will indicate if any one of these components works better with either e-KM or the instructor.

Psychometric Analysis

Reliability

Cronbach's alpha is a reliability model commonly used as measure of reliability in assessment instruments. It is a model of internal consistency, based on the average inter-item correlation. Conventionally, when the Cronbach's alpha coefficient is greater than .70 an assessment instrument is said to have acceptable reliability. The alpha coefficient for the Study 1 is $\alpha = .80$ indicating its reliability.

Item Analysis for Study 1

The purpose of an item analysis is to determine the difficulty and discrimination of each item; it provides information regarding the difficulty (the percentage of the group tested that answered the question correctly) and the discrimination (how well the item distinguishes between the more knowledgeable and less knowledgeable students) of the items on the test. If all students mark an item incorrectly, then the item has no discriminating power within the group and does not assess individual differences. In depth item analysis indicated questions 5, 7, 16 and 28 required revisions.

Method

1) Take the highest 1/3 of the test: this is the “high scoring group”. (N=56, n=18)

2) Take the lowest 1/3 of the test: this is the “low scoring group”

3) Determine the Proportion in ‘high’ group (P_H)

$$P_H = \text{number of correct responses to item} / n$$

4) Determine the Proportion in ‘low’ group (P_L)

$$P_L = \text{number of correct responses to item} / n$$

5) Estimated item difficulty index, p is the average of P_H and P_L

$$p = (P_H + P_L) / 2$$

6) Measure of item discrimination index, D (distinguish between the more knowledgeable students and the less knowledgeable students)

$$D = P_H - P_L$$

Table 15 Item analysis for Study 1

Item	**# of Correct for All**	**# of Wrong for All**	**# Correct for High Ranking Students**	**PH**	**# Correct for Low Ranking Students**	**PL**	**p**	**D**

Q1	49	7	18	1.00	11	0.61	0.81	0.39
Q2	43	13	16	0.89	14	0.78	0.83	0.11
Q3	28	30	15	0.83	2	0.11	0.47	0.72
Q4	47	9	17	0.94	12	0.67	0.81	0.28
Q5	52	4	18	1.00	15	0.83	0.92	0.17
Q6	42	14	18	1.00	8	0.44	0.72	0.56
Q7	14	42	7	0.39	4	0.22	0.31	0.17
Q8	40	16	16	0.89	6	0.33	0.61	0.56
Q9	47	9	20	1.11	11	0.61	0.86	0.50
Q10	41	15	16	0.89	13	0.72	0.81	0.17
Q11	47	9	17	0.94	12	0.67	0.81	0.28
Q12	34	22	17	0.94	4	0.22	0.58	0.72
Q13	39	17	17	0.94	6	0.33	0.64	0.61
Q14	17	39	13	0.72	2	0.11	0.42	0.61
Q15	29	27	15	0.83	4	0.22	0.53	0.61
Q16	52	4	17	0.94	16	0.89	0.92	0.06
Q17	39	17	16	0.89	6	0.33	0.61	0.56
Q18	18	38	12	0.67	2	0.11	0.39	0.56
Q19	24	32	15	0.83	2	0.11	0.47	0.72
Q20	36	20	18	1.00	5	0.28	0.64	0.72
Q21	45	11	17	0.94	10	0.56	0.75	0.39
Q22	38	18	14	0.78	11	0.61	0.69	0.17
Q23	49	7	15	0.83	15	0.83	0.83	0.00
Q24	26	30	13	0.72	6	0.33	0.53	0.39
Q25	45	11	20	1.11	10	0.56	0.83	0.56
Q26	30	26	11	0.61	10	0.56	0.58	0.06
Q27	25	31	13	0.72	4	0.22	0.47	0.50
Q28	49	7	17	0.94	16	0.89	0.92	0.06
Q29	45	11	14	0.78	14	0.78	0.78	0.00
Q30	47	9	16	0.89	13	0.72	0.81	0.17

Items Q5(p=.92; 92%) Q16(p=.92; 92%) and Q28 (p=.92, 92%) had a large percentage of students respond correctly, indicating the items were very easy.

Item Q7 (p=.31, 31%) only had 31% answering it correctly indicating it was a difficult question, beyond their scope of knowledge. (Table 15)

Items that yield a discrimination index of 0.30 or more are relatively good in distinguishing between knowledgeable and less knowledgeable students, and those with D values below 0.10 are relatively low in discrimination. Items that were miskeyed or intrinsically ambiguous will tend to have very low or negative D values. Q5 (D=0.17), Q7 (D=0.17), Q16 (D=0.06) and Q28 (D=0.06) all had D index values indicating their inability to distinguish between knowledgeable and less knowledgeable students. Furthermore, an item discrimination index from an item analysis generally agrees with independent subjective evaluation of the item quality. Reviewing the "raw" data, it appeared Q5, Q7, Q16 and Q28 were low in their discriminating ability.

As Q5, Q7,Q16 and Q28 each failed to discriminate amongst students, each was re-written for Study 2.

Repetitive Access

The frequency table gives us information on the number of clicks, thus the sub-set question, "Do the students repeat watching elements of e-KM more than once?" is answered is answered based on this.

Table 16: Number of clicks for Study 1

	Number Of clicks	**Frequency**	**Percent**	**Cumulative percent**
Video Clicks				
	1	8	25.8	25.8
	2	11	35.5	61.3
	3	8	25.8	87.1
	4	4	12.9	100.0
Pearls Clicks				
	1	3	9.7	9.7
	2	22	71.0	80.6
	3	6	19.4	100.0
Illustration Clicks				
	1	18	58.1	58.1
	2	11	35.5	93.5
	3	2	6.5	100.0

Further analysis of ANOVA indicates there is a significant difference between 1click, 2clicks, 3clicks, and 4clicks affecting total scores. Students with 1click or 2clicks had scores of 15.30 and 16.40, those with 3clicks and 4clicks had higher scores of 24.0 and 25.80 respectively.

Table 17: Pearson Product Moment Correlation of Total Score and Video Engagement.

	Total score	Pearl Access time	Illustration Access time	Video Access time	Video clicks	Pearl clicks	Illustration clicks
Pearson correlation	1	.258	.165	.858**	.678**	.291	.108
Pearl access time	.258	1	.304	.261	.359*	-.072	-.107
Illustration access time	.165	.304	1	.282	.379*	-.185	-.301
Video access time	.858**	.261	.282	1	.825**	.305	.160
Video clicks	.678**	.359*	.379*	.825**	1	.22	.114
Pearl clicks	.291	-.072	-.185	.305	.200	1	.351
Illustration clicks	.108	-.107	-.301	.160	.1	.351	1

** Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed)

As seen, there is a significant correlation between the total score and video access time and number of video clicks. As well, correlation occurs between video clicks and pearl access time, video access time and illustration access time.

Regression Analysis

Table 18: Backward Elimination Regression model summary for Study 1

Model	Sum of square	df	Mean square	Beta	R square	F	Sig
Regression	795.02	1	795.02	0.858(a)	0.73	80.92	0.00
Residual	284.91	29	9.85				
Total	1079.93	30					

Independent variable: video access time
Dependent variable: test scores

In regression analysis, all independent variables selected are added to a single regression model. All variables must pass the tolerance criterion to be entered in the equation regardless of the entry method specified. In stepwise regression analysis, at each step, the independent variable not in the equation which has the smallest probability of F is entered; variables already in the regression equation are removed if their probability of F becomes sufficiently large. The method terminates when no more variables are eligible for inclusion or removal. Stepwise regression can have forward selection or backward selection model. In forward selection in a stepwise model, variables are sequentially entered into the model. The first variable considered for entry into the equation is the one with the largest positive or negative correlation with the dependent variable. This variable is entered into the equation only if it satisfies the criterion for entry. If the first variable is entered, the independent variable not in the equation that has the largest partial correlation is considered next. The procedure stops when there are no variables left that meet the entry criterion.

In backward elimination, all variables are entered into the equation and then sequentially removed. The variable with the smallest partial correlation with the dependent variable is considered first for removal. If it meets the criterion for elimination, it is removed. After the first variable is removed, the variable remaining in the equation with the smallest partial correlation is considered next. The procedure stops when there are no variables in the equation that satisfy the removal criteria.

For the study, backward elimination regression analysis was employed where the student test score is the dependent variable; video access time, illustration access time, pearl access time, video clicks, illustration clicks, pearl clicks are all independent variables.

Regression analyses indicated video access time as the only significant predictor impacting the test score (Table 18).

Summary of Study 1

Since the statistic and significant value for Kolmogorov-Smirnov and Shapiro-Wilk indicated the data are normally distributed, an analysis of variance and regression analysis were performed. Descriptive statistics provided the mean, variance, and standard deviation. Analysis of variance yielded a significant value of 0.24 indicating there was no significant difference between the e-KM group and the surgeon group impacting total score.

Cronbach's reliability test for the test instrument yielded an alpha coefficient of $\alpha = 0.80$.

Regression analysis indicated video access time as the only significant predictor impacting the total test score. Furthermore, no other items were identified as having an impact on the test scores.

The ANOVA for overall clicks indicated a significant difference between the numbers of clicks and their impact on total score. F value at 10.02 ($p<.05$) indicated there was a significant difference between 1click, 2clicks, 3clicks, and 4clicks. The video access time and number of video clicks had a significant impact on the total test scores as well. The total score was higher for those students who accessed the video via 3(clicks) or 4(clicks) spending more time viewing the video.

Correlation analysis indicated a significant correlation between total score and video access time and video clicks. The correlation coefficient gave credence to the regression model and the ANOVA analysis

Answering the research questions:

"Can an electronic Knowledge Model (e-KM) of a surgical procedure enhance knowledge acquisition among learners?"; data indicates there is no significant difference between e-KM and the surgeon instructor group. The sub-set of questions and responses provide a deeper insight to e-KM's impact on knowledge acquisition.

1) *Do the students repeat watching elements of e-KM more than once?*

As recorded (Table 17), the students did watch elements of e-KM more than once; the percentage was calculated based on e-KM's group of 31 participants. 36% of the students watched the video more than once. 36% of the students looked at the illustration more than once and 71% of the students read through the "pearls" more than once

2) *Is there a difference between the groups (e-KM and surgeon instructor) with respect to knowledge acquisition?*

There was no significant difference between the e-KM group and the surgeon group. An 8% difference in the mean favoring the surgeon was detected.

3) *Does video access time, pearls access time and illustration access time have an impact on total test scores?*

The results from the statistics (regression and correlation) show video access time impact test scores significantly (significant at 0.01 level). Pearls access time and illustration access time impact test scores as well (significant at 0.05 level).

4) *Does the number of video clicks have an impact on total test scores?*

As seen in Table 18, the test scores were impacted by the number of video clicks; higher scores were correlated with higher number of clicks.

Study 2

The data was assumed to be normal in Study 2 since there was no variation in the sample population (class of 2010). Study 2 had 50% class participation, 30 in the surgeon group and 32 in the e-KM group for a total sample size of 62.

Descriptive Statistics

Table 19: Descriptive Statistics for Study 2

Group	N	Mean	Std. Deviation	Variance
e-KM	32	27.00	4.36	19.09
Surgeon	30	28.90	3.39	11.54
Total	62	27.91	4.01	16.10

Descriptive statistical analysis yielded a mean value for e-KM as 27.00 (SD=4.36) and a mean value for surgeon as 28.90 (SD=3.39). The variance for e-KM is 19.09 and the variance for surgeon is 11.54. There was no significant difference between the e-KM group and the surgeon group. ($F(1,60) = 3.6$, $p > .05$).

Psychometric Analysis

Reliability

Cronbach's alpha for reliability was 0.70 hence the test instrument was accepted as reliable. Resulting from item analysis of MCQs for Study 1, the Study 2 test was modified. The revised test consisted of 35 MCQs,. Five new questions were added to test professionalism, clinical behaviours, and informed consent. Questions Q5, Q7, Q16 and Q28 were re-written.

The changes in Study 2 were as follows:

The word “long-term” in Q5, was considered confusing; therefore it was removed from option 1). In Q7, 1% dosage as an option for anaesthetic was deliberately misleading and was changed to 10% in option 1) and 3).

For Q28, presenting *E.coli* as an option removed ambiguity; the change was made to *clostridium botulinum*. For Q16, options 2) and 4) were introduced to increase the difficulty of the question.

The new versions of the questions read as follows:

Q5) COUMADIN can be best described as

1) Anticoagulant

2) Inhibits B-dependent clotting factors II, VII, IX,X

3) The half-life effect is 200 hours

4) Monitored effects by partial thromboplastine time (PTT)

Q7) What is the dosage of lidocaine that can be used as a local anaesthetic?

1) 10% lidocaine; 20mg/kg

2) 1% lidocaine with epinephrine; 7mg/kg

3) 10% lidocaine; 7mg/kg

4) 1% lidocaine with epinephrine; 20mg/kg

Q16) Which one of the following is not the correct treatment for the cyst

1) Surgery

2) Injection of luorouracil (2-Fu)

3) Injection of steroid

4) Injection of 5-fluorouracil (5-Fu)

Q28) Post operative wound infection is least likely to be caused by

1) Staphylococus aureus

2) Staphylococus epidermidis

3) Group A Streptococus

4) Clostridium botulinum

Item analysis

Steps of an Item Analysis for Study 2

1) Take the highest 1/3 of the test: this is the "high scoring group". (N=62, n=20)

Score of 30> was classed as 'high'

2) Take the lowest 1/3 of the test: this is the "low scoring group"

Score of 25< was classed as 'low'

Table 20: Item analysis for Study 2

Item	# of Correct for All	# of Wrong for All	# Correct for High Ranking Students	PH	# Correct for Low Ranking Students	PL	p	D
Q1	47	15	19	0.95	9	0.55	0.75	0.40
Q2	44	18	17	0.85	12	0.60	0.73	0.25
Q3	44	18	17	0.85	9	0.55	0.70	0.30
Q4	47	15	19	0.95	9	0.55	0.75	0.40
Q5	48	14	18	0.90	12	0.65	0.78	0.30
Q6	55	7	19	0.95	16	0.90	0.93	0.05
Q7	46	16	20	1.00	9	0.50	0.75	0.50
Q8	53	9	19	0.95	13	0.75	0.85	0.20
Q9	55	7	19	0.95	16	0.90	0.93	0.05
Q10	40	22	17	0.85	10	0.50	0.68	0.35
Q11	46	16	20	1.00	9	0.50	0.75	0.50
Q12	44	18	17	0.85	11	0.65	0.75	0.20
Q13	53	9	19	0.95	14	0.80	0.88	0.15
Q14	39	23	18	0.90	4	0.20	0.55	0.70
Q15	15	47	11	0.55	3	0.15	0.35	0.40
Q16	47	15	19	0.95	9	0.55	0.75	0.40
Q17	54	8	20	1.00	14	0.80	0.90	0.20
Q18	22	40	15	0.75	3	0.15	0.45	0.60
Q19	32	30	19	0.95	2	0.10	0.53	0.85
Q20	48	14	20	1.00	10	0.60	0.80	0.40
Q21	54	8	19	0.95	17	0.95	0.95	0.00
Q22	51	11	19	0.95	14	0.80	0.88	0.15
Q23	47	15	19	0.95	9	0.55	0.75	0.40
Q24	35	27	17	0.85	7	0.35	0.60	0.50
Q25	47	15	19	0.95	9	0.55	0.75	0.40
Q26	36	26	16	0.80	12	0.60	0.70	0.20
Q27	47	15	19	0.95	9	0.55	0.75	0.40
Q28	43	19	18	0.90	11	0.55	0.73	0.35
Q29	47	15	19	0.95	9	0.55	0.75	0.40
Q30	47	15	19	0.95	9	0.55	0.75	0.40
Q31	44	18	12	0.60	16	0.90	0.75	0.30
Q32	49	13	**19**	0.95	12	0.70	0.83	0.30
Q33	42	20	12	1.10	10	0.60	0.85	0.50
Q34	54	8	20	1.00	14	0.80	0.90	0.20
Q35	51	11	18	0.90	14	0.70	0.80	0.20

The revised questions Q5(D=.30, p =.78), Q7(D=.50, p = .75), Q16(D=.40, p = .75) and Q28(D= .35, p=.73) improved in their ability to distinguish between knowledgeable and less knowledgeable students (Table 20).

The new MCQs testing professionalism, clinician behaviour and informed consent values are: Q31(D=.30, p=.75), Q32(D=.30, p=.83), Q33(D=.50, p=.85), Q34(D= -.05, p=.83), Q35(D=-.20, p=.80). Q31 and Q32 performed well in distinguishing between knowledgeable and less knowledgeable students, their D value being greater than .30. Q34 and Q33 performed inadequately in discriminating. Percentage wise, 75% answered Q31 correctly, 83% answered Q32 correctly, 85% answered Q33 correctly, 83% answered Q34 correctly and 80% answered Q35 correctly.

Repetitive Access

Based on the information the frequency table provides on the number of clicks the sub-set question “Do the students repeat watching elements of e-KM more than once?” is answered.

Table 21: Number of clicks for Study 2

	Number Of clicks	**Frequency**	**Percent**	**Cumulative percent**
Video Clicks				
	1	4	12.5	12.5
	2	16	50.0	62.5
	3	11	34.4	96.9
	4	1	3.1	100.0
Pearls Clicks				
	1	11	34.4	34.4
	2	21	65.6	100.0
Illustration Clicks				
	1	18	56.3	56.3
	2	13	40.6	96.9
	3	1	3.1	100.0

The mean value for total score for students with 1click or 2clicks was 22.5 and 25.7 respectively, those with 3clicks and 4clicks had higher scores of 30.1 and 32.0 respectively. ANOVA ($p<.05$) indicated there was a significant difference between 1click, 2clicks, 3clicks, and 4clicks impacting total scores.

Table 22: Pearson Product Moment Correlation of Total Score and Video Engagement for Study 2

	Total score	Pearl Access time	Illustration Access time	Video Access time	Video clicks	Pearl clicks	Illustration clicks
Pearson correlation	1	-.085	.002	.841**	.628**	.490	-.052
Perl access time	-.085	1	.381*	-.018	-.068	.116	-.320
Illustration access time	.002	.381*	1	.165	.189	.148	-.019
Video access time	.841**	-.018	.165	1	.175**	.611**	-.119
Video clicks	628**	-.068	.186	.715**	1	.375*	.061
Pearl clicks	.490	.116	.148	.611**	.375*	1	-.099
Illustration clicks	-.052	-.320	-.019	-.119	.061	-.099	1

**Correlation is significant at 0.01 level (2-tailed). * Correlation is significant at 0.05 level (2-tailed)

Table 22 indicates a significant correlation between the total score and video access time, video clicks and pearl clicks.

Regression Analysis

Regression analysis indicates (Table 23) video access time as the only significant predictor ($p<.05$) impacting the test score.

Table 23 Backwards Elimination Regression for Study 2

Model	**Sum of square**	**df**	**Mean square**	**Beta**	**R square**	**F**	**Sig**
Regression	418.62	1	418.62	0.841	0.707	72.43	0.00
Residual	173.37	30	5.77				
Total	592.00	31					

Independent variable: video access time
Dependent variable: test Score

Summary of Study 2

Descriptive statistical analysis yielded a mean value for e-KM as 27.00(SD=4.36) and a mean value for surgeon as 28.90 (SD=3.39). The variance for e-KM was 19.09 and the variance for surgeon was 11.54.

There was no significant difference between the e-KM group, and the surgeon group ($p >.05$).

Reliability test for the Test Instrument yielded an alpha coefficient of 0.70, thus it can be stated the test instrument used for the Study was reliable.

Regression analysis indicated video access time as the only significant predictor impacting the total test score. Furthermore, no other items were identified as having an impact on the test scores.

The ANOVA for overall clicks indicated a significant difference ($p<.05$) between the numbers of clicks and their impact on the total score. The video access time and number of video clicks had a significant impact on the total test scores as well. The total score was higher for those students who accessed the video more than twice.

Correlation analysis indicated there was a significant correlation between total score and video access time, pearl clicks and video clicks. The correlation coefficient gave credence to the regression model and the ANOVA analysis. There was a significant correlation between the total score and video access time, pearl clicks and number of video clicks. This further supported the conclusions derived from the ANOVA and regression analysis.

Answering the research question

The response to the overarching question "Can an electronic Knowledge Model (e-KM) of a surgical procedure enhance knowledge acquisition among learners?" was again that there is no significant difference between e-KM and the surgeon instructor ($p>.05$). However, the subsequent questions and responses provide insight to e-KM's impact on knowledge acquisition.

1) *Do the students repeat watching elements of e-KM more than once?*

As recorded, the students did watch elements of e-KM more than once, the percentage was calculated based on the e-KM group of 32 participants. 84% of the students watched the video more than once. 44% of the students looked at the illustration more than once. 66% of the students read through the 'pearls' more than once.

2) *Is there a difference between the groups (e-KM and Surgeon instructor) with respect to knowledge acquisition?*

There was no significant difference ($p>.05$) between the e-KM group and the Surgeon instructor. However, a 7% difference in the mean could be calculated.

3) *Does video access time, pearls access time and illustration access time have an impact on total test scores?*

The results from correlation (Table 22) and regression (Table 23) indicate access time impact test scores significantly. Video access time had a significant impact on test scores.

4) *Does the number of video clicks have an impact on the total test scores?*

As seen (Table 21) the test scores were impacted by the number of video clicks and pearls clicks; higher scores were correlated with higher a number of clicks.

Overall summary of results for Study 1 and Study 2

The average participation of the class of 2009 and 2010 Undergraduate medical students was 48%. Descriptive statistics for the combined data of Study l and Study ll yielded e-KM mean (23.19), variance (42.18) and standard deviation (6.49). For the surgeon group the mean was (25.25), variance (28.37) and standard deviation (5.32). A 9% difference in the mean between e-KM and surgeon data was detected in favour of the surgeon and analysis of variance indicating there was no significant difference between the e-KM group and the surgeon group in test performance impacting total score.($p>0.05$)

The revised MCQ for Study 2 was reliable in assessing ($\alpha=0.07$) student's knowledge. The new questions addressing informed consent and confidentially (Q31, Q35) performed inadequately in discriminating between students.

Regression analysis indicated video access time was a significant predictor impacting the total test score, additionally pearls clicks had an impact as well.

The ANOVA for clicks indicated a significant difference between the numbers of clicks and their impact on total score. Access time had a significant impact on the total test score as well; i.e. video access ($p<0.05$) pearl access time ($p<0.05$), illustration access time ($p<0.05$); more time on task impact total scores. Correlation analysis indicated there was a significant correlation between total score and video access time, video clicks and pearl access time.

Analysis of both studies confirmed there was no significant difference between e-KM and surgeon. Increased video access and increased number of clicks have a positive impact on knowledge acquisition.

CHAPTER 5: DISCUSSION

General summary of major findings

The test scores were normally distributed with 48% student participation between the class of 2009 and 2010 Undergraduate medical students at the University of Alberta. The analysis of data indicated there were no significant difference between e-KM and the surgeon group. Frequency analysis showed that students accessed elements of e-KM more than once, in particular pearls were accessed more compared to video or illustrations. Additionally, the number of clicks had a significant impact on test scores. The maximum number of clicks to access any one element of e-KM was four. Stepwise regression analysis indicated video access time was significantly related to test score. Correlation analysis indicated a significant correlation between video access time, pearls access time (teaching points), and illustration access time, with the number of clicks all having an impact on test scores.

Detailed major results

Analysis of variance for Study 1 yielded e-KM's mean = 19.25, standard deviation = 5.99, variance = 35.99. The human teacher surgeon) mean = 20.88, standard deviation = 3.65, variance =13.36. Frequency analysis indicated a significant difference between the number of clicks and their impact on total scores ($p<.05$). More than one-third (36%) accessed the video more than once, 71% accessed pearls more than once and 35% accessed illustrations more than once. Reliability analysis of the MCQ test produced an alpha value of 0.80. Item analysis for Study 1 identified that Q5 (D=.17, P=.92), Q7 (D=.17, P=.31), Q16 (D=.06, P=.92), Q28 (D=.06, P=.92) all performed inadequately in discriminating between knowledgeable and less knowledgeable students. These questions were re-written for Study 2.

Analysis of variance for Study 2 yielded e-KM's mean = 27.00, standard deviation = 4.36, variance = 19.09 and surgeon's mean = 28.90, standard deviation =3.39, variance=11.54, further, $F = 3.60$, $p>0.05$. Frequency analysis indicated a significant difference between the numbers of clicks and their impact on scores ($p<.05$). Half of the participants (50%) accessed the video more than once, 66% accessed pearls more than once and 40% accessed illustrations more than once. Reliability test to assess the MCQ test produced an alpha value of 0.70. Item analysis for the five new MCQs testing professionalism, clinician behaviour and informed consent, produced Q31 (D=.30, P=.75), Q32 (D=.30, P=.83), Q33(D=.50, P=.85), Q34(D=-.05, p=.83), Q35(D=-.20, P=.80). Q31, Q32 and Q33 performed well in distinguishing between knowledgeable and less knowledgeable students, however, Q34 performed inadequately in discriminating between students and Q35 was acceptable. The revised questions Q5 (D=.30, P=.78), Q7(D=.50, P=.75), Q16(D=.40, P=.75) and Q28(D=.35, P=.73) all performed well in Study 2.

The analysis of combined data for Study 1 and Study 2 yielded e-KM's mean = 23.19, standard deviation = 6.49, variance = 42.18 and surgeon's mean = 25.25, standard deviation = 5.32, variance=28.38, further, F = 3.49, p>.05, indicating no significant difference between e-KM groups and surgeons group. Stepwise regression analysis indicated video access time as a significant predictor impacting test scores. Correlation analysis indicated a significant correlation between test scores and video access time, video clicks and pearls access time.

Discussion

Flexner's report, a century ago (1), addressed many of the fundamental issues in Medical Education philosophy. i.e. "*when should clinical training occur?, how much time should be spent in clinical training?, when should content be taught?, when does observational and experiential learning take place?, who should be permitted to study medicine?, who governs the program?, who accredits the program? and who funds it?*" Although the solutions have evolved and metamorphosed many times, 100 years later the questions still persist.

In the 21st century, technology has become important in addressing current expectations and demands placed on teaching in medical schools (122, 145, 151, 201, 211, 341, 342). The expectation of incorporating new knowledge and information, into existing programs has created time pressures. Additionally, limited resources (staff and facilities), cost of administration, academic regulations, policies and competing curricula have further compounded the situation (3, 25, 27, 43, 235, 343). Opportunities for learning through “real” patients are diminishing, partially due to medical malpractice concerns and regulations. In the emerging teaching model, technology based simulations are beginning to play a significant role. It is critical to study the efficacy of these technology models to provide the best teaching environments to students. These models are sometimes championed by technology enamoured instructors who might lose sight of the objective of the curricula, hence an efficacy study would be prudent (26, 344, 345).

Apart from addressing the efficacy of e-KM, the present study has provided insight into knowledge acquisition. From the frequency count for pearls (Study 1 = 71%, Study 2 = 66%) it was evident that students preferred this than large volumes of information. Even when experimental time was not a limiting factor, the students did not access video bytes, illustrations or pearls more than four times. The percentage for access more than once for video was (Study 1 = 36%, Study 2 = 50%), pearls (Study 1 = 71%, Study 2 = 66%), and illustrations (Study 1 = 35%, Study 2 = 40%). Even though the allotted time was two hours for the study the students left the room once they answered the test. According to the frequency study the maximum number of clicks the students were prepared to spend in order to learn was four. This leads to postulate that four clicks might be the limit of clicks a student is willing to invest in the process of learning. Further studies are required to explore this possibility. It needs to be noted that a larger percentage of students (Study 1 = 71%, Study 2 = 66%) accessed pearls more than once, compared to video and illustrations.

Correlation and regression analysis indicate the time spent on task whether it be viewing the video, reading the pearls or illustrations, had a significant impact on knowledge acquisition; therefore, it can be stated that increased time on task increases test scores. Even though there was no significant difference between the scores from the surgeon group and e-KM group, there was a 9% difference between the mean (even though statistically non-significant), where the human teacher group had the higher mean. Many factors may have contributed to the difference, such as the instructor's ability to engage class participation, class engagement, presentation of material, face-to-face instruction modelling effects, varied learning styles and learning preferences of students. Further studies need to be conducted to investigate these factors.

In analysing why some electronic knowledge models fail to capture the attention of learners, it was evident from this study that the presentation of material and accessibility are key factors. Careful consideration was given to the dissemination of information including concise text, colours, fonts and size of the video byte. Utilizing current technology, e-KM was designed to be accessible on varied platforms (Windows, Mac). Limiting the models to one computer platform limits access, defeating the purpose of anywhere anytime assess to knowledge.

Phase 2 of the study was to design an assessment instrument with acceptable validity. This required a team of experts in the field of medicine, computer science and medical education. The medical educationist's expertise in pedagogy was required to design a successful assessment instrument, clinical experts were needed for content validity, and computer scientists were required for technical design. For the study, three surgeons, three family physicians and one nurse contributed towards content. To achieve consensus among the team members on MCQs and table of specification for the construction of the test was challenging. Because of busy schedules meetings were often cancelled. However, in order to develop e-KM it was imperative the various experts provide input towards the design of the test. Empirical evidence shows assessment methods in surgery are often developed with limited resources and time constraints. Because of this, the validity of the instruments often does not adhere to pedagogical constructs such as item analysis or table of specification for the learning objectives. Therefore, understanding the importance of team effort is critical and needs to be fostered in institutions.

Constructing tests and interpreting test scores are a crucial part of formal education. Models such as the Classical Test Theory and Item Response Theory serve examiners well, since the assumptions of these models can be met by most test data. The two key psychometric properties that give credence to analysis of test data are reliability and validity. Surgical skill assessment methods pose a unique set of problems in constructing reliable and valid instruments for assessment. The development of these tests have inherent problems due to their environment (operating room), hospital policies, liabilities, human resources, cost, and time limits; often single tests are given on one occasion. The credibility of the results depends on the reliability and validity measures of the test, therefore, attention needs to be paid when constructing test instruments.

The study was based on Fits-Posner stage theory (8, 346) for skill learning and current surgical training models (Table 7) developed from a combination of foundational learning theories (Table 5) and modern learning theories (Table 6). In the three stages of Fits- Posner model, the surgical skill learning is initiated at the cognitive stage (first stage) with observation being a critical element. As students observe the surgical procedure via the video clip they begin to understand how the procedure is performed. Observational Learning occurs through observing and modeling (40, 347). From observing others the learner acquires cognitions and new behaviours or skills are performed, and on later occasions this coded information serves as a guide for action. In the study Observational Learning occurs watching the video clip of cyst removal for both groups. In the e-KM group unlimited access observing the video clips had a significant impact on test scores.

From the current surgical models Evidence Based Medicine and Observational Learning formed the bases of this study. Evidence Based Medicine is rooted in Cognitive Theory, Cognitive Load Theory, Information Processing Theory and Social Learning Theories (347-353). In Cognitive Theory and

Cognitive Load Theory the focus is on memory development, combination of elements as a structure of knowledge, evaluation, perception, understanding and in-context decision making. Combination of elements that form knowledge was achieved by presenting information in different formats, ie;, text, verbal, graphical, pearls, human interaction, video bytes. The results of this indicate increased access to elements such as video bytes and pearls had a significant impact on test scores. The instructor describing the case verbally and e-KM having a case history; the understanding and in-context decision making was achieved as the learning objective for diagnosis.

Social Learning Theory and Information Processing Theory focus on observing, cognitive processing, repetition, coding, chunking, short-term memory, learner-centeredness and modelling (347, 352-355). All these elements were taken into consideration as pedagogical underpinnings while constructing the teaching model for the study. However, learner-centeredness, ie;, learning at their own pace, unlimited access to e-KM, repetitive observation of video clips, repeated access to pearls and illustrations were the dominate focus for e-KM group.

Limitations of the e-KM System

A limitation of e-KM is that requires high technical surroundings. Therefore, computer system crashes can occur when computer memory or capacity was taxed. If video bytes require large capacity for computer memory and if the intended system cannot support the requirement, it would crash causing learner frustration. Broken web site links are a common problem; when an institution makes changes within their existing system connections to existing links are often lost, unless attention is paid to maintaining these links, access becomes limited or lost. Another issue would be an incompatible operating system (Mac vs. Windows). Models developed on unique platforms are not accessible. Further, inadequate infrastructure to support e-KM within medical education would restrict development. Support for e-KM includes digital libraries, consensus on technical standardization and methods for peer review. Unless there is support form faculty, these challenges will contribute towards an unstable e-learning environment.

From a student perspective, learner isolation is a factor; with e-KM human interaction becomes limited. Some students prefer human interaction and learn better when surrounded by colleagues and classmates (41, 93, 142, 147, 356). Additionally human instructors provide the humanistic touch, personal engagement and positive social learning environments that create a positive learning experience. e-KM might also create a false sense of "observational learning" thereby creating apathy in operating rooms; this could extend to clinical practices in real environments. As discussed previously designing an electronic knowledge model is a team effort with physicians, computer scientists and medical educationist contributing to the collective success of the model. Although building a cohesive team is a challenge it should not be a deterrent.

Comparison

In an accreditation process of a medical program its electronic knowledge models are scrutinized for their efficacy and fidelity and their success has to be demonstrated for sustainability. Current models of simulation used in medical education include inanimate models, virtual reality, live animals, human cadavers, patient simulators, and robotics. These varied models range from high fidelity to low fidelity. Cadavers are the closest approximation to reality and are ranked as high fidelity, however, cost and limited availability restricts access to cadavers. In contrast e-KM is a safe model, re-usable, low-cost, minimal risk and provides unlimited access. Another comparison would be an animal model; this too is high fidelity, but it requires special facility, single use, anatomical differences, and contains ethical considerations to comply making it prohibitive. Conversely, e-KM is multiple use and resides in one computer.

Another comparator to e-KM is the human performance simulator (mannequins) with high fidelity and high cost associated with it; technology has to be further developed to simulate realism closely. In the spectrum of fidelity, e-KM can be classed as having medium-fidelity and is best applicable in early stages of learning, teaching basic skills to novice learners.

In addressing the efficacy of e-Km, it can be stated that it is reliable and eliminates instructor variability providing consistency. e-KM has the capacity to disseminate standardized curriculum regardless of physical location, providing access to curricular materials and learning resources at any given time and place. There is greater control over pacing and sequencing of content delivery and an opportunity for content review, therefore making it a dependable educational tool.

It is apparent from the data that increased access (number of clicks) and increased time on task (video access time) has a positive impact on knowledge acquisition. e-KM provides a standardized teaching model eliminating instructor variability. Students have unlimited access to e-KM unlike the one time access to instructor. This model may provide a generic framework for other educational programs and disciplines, particularly other surgical procedures. e-KM also provides research opportunities for faculty.

Limitations of the Study

The findings are based on a relatively small sample size of 118 participants from one academic institute. An increased sample size pooled from multiple academic institutions would provide robust results enhancing the conclusion of the present studies. Assessment was limited to cognitive knowledge testing only. A comprehensive surgical assessment would include observation of skills and attitudes as well. Direct observation and video recording of skill performance are common forms of assessments (15, 54, 134, 151, 199, 357). However other technologies such as virtual reality (mannequin), digital and tele-health can also used to assess skills (196, 358). Skill assessment was beyond the scope for the present study, but should be incorporated in future research.

Attitudes are commonly tested via written Likert type items (e.g., strongly agree to strongly disagree)., Since the focus of assessment for the present study was testing cognitive knowledge acquisition for a surgical procedure, the MCQs were designed with content strata focusing on testing cognitive knowledge. Therefore, attitude assessment was not conducted in the present study but should be incorporated in future research. Specifically, attitudes towards learning from a human teacher compared to learning from the e-KM can be studied in future work.

Conclusion

Effective medical education will increasingly require innovative approaches to the delivery of curricula. The underpinnings of established theories can be explored in the teaching and learning models in surgery. In surgery, the educational process is more in alignment with the definition of a model than theory and many of the models are borrowed from other disciplines. Currently, successful training models supported by technology are becoming common in medical education. Efficacious models such as e-KM are gaining support in the curricula (23-25, 122, 148, 234, 345, 359). The e-KM has the advantage of unlimited access providing increased learning opportunities. Thus in environments where instructors are not accessible, e-KM can be substituted for human instructors or used as an additional tool. This will be particularly important in remote and rural teaching environments. A key element in the successful use of e-KM is that it becomes integrated throughout the entire curriculum so that purposeful practices to acquire knowledge over time are possible.

This thesis has addressed the efficacy of e-KM and its impact on knowledge acquisition. As shown in the thesis, increased time spent with e-KM has a positive impact on knowledge. Therefore the answer to the research question, "Can an electronic Knowledge Model (e-KM) of a surgical procedure enhance knowledge acquisition among learners?" can be stated as *"Yes, an electronic Knowledge Model (e-KM) of a surgical procedure will enhance knowledge acquisition among learners."*

The application of clinical knowledge and the development of skills in surgery require deliberate and meaningful scenarios. As medical education continues to evolve e-KM presents part of the solution to challenges that are currently faced by academic institutions.

Reference

1. Flexner A. Medical Education in the United States and Canada. The Flexner Report. 1910.
2. Dunphy BC, Williamson SL. In pursuit of expertise. Toward an educational model for expertise development. Adv Health Sci Educ Theory Pract. 2004;9(2):107-27.
3. Gibbs T. Medical education--will we ever get it right? S Afr Med J. 2002 Aug;92(8):609-10.
4. Regehr G. Trends in medical education research. Academic Medicine. 2004(79 (10)):939-47.
5. Wolf FM, Schaad DC, Carline JD, Dohner CW. Medical education research at the University of Washington School of Medicine: lessons from the past and potential for the future. Acad Med. 2004 Oct;79(10):1007-11.
6. Geha AS. Medical education and the training of cardiothoracic surgeons in the United States of America. J Thorac Cardiovasc Surg. 2005 Jun;53(6):320-3.
7. Fabri PJ. Lessons learned at sea--ocean sailing as a metaphor for surgical training. Am J Surg. 2003 Sep;186(3):249-52.
8. Reznick RK, MacRae, H. Teaching Surgical Skills -- Changes in the wind. New England Journal of Medicine. 2006;355::2664-9.
9. Gandsas A, McIntire K, Palli G, Park A. Live streaming video for medical education: a laboratory model. Journal of Laparoendoscopic & Advanced Surgical Techniques-Part A. 2002 Oct;12(5):377.
10. Mayo GL, Lindhorst GC, Rosende C. American ophthalmology graduate medical education and the web: current state of internet resource utilization. American Journal of Ophthalmology. 2003 May;135(5):708.
11. Webber WB, Rinehart GC. Computer-based multimedia in plastic surgery education. Proc Annu Symp Comput Appl Med Care. 1992:829-30.
12. Izzat MB, El-Zufari MH, Yim AP. Training model for "beating-heart" coronary artery anastomoses. Ann Thorac Surg. 1998 Aug;66(2):580-1.
13. Crowley RS, Medvedeva O. An intelligent tutoring system for visual classification problem solving. Artif Intell Med. 2005 Aug 9.
14. Newton BW BL, Clardy J, Cleveland E, O'Sullivan P. Is there hardening of the heart during medical school? Acad Med 2008; Mar;83(3):244-9(March 2008).
15. Cosman PH, Cregan PC, Martin CJ, Cartmill JA. Virtual reality simulators: current status in acquisition and assessment of surgical skills. ANZ J Surg. 2002 Jan;72(1):30-4.

16. Uranus S, Yanik M, Bretthauer G. Virtual reality in laparoscopic surgery. Stud Health Technol Inform. 2004;104:151-5.
17. Carati C SS, Okamura K, Lomanto D, Tanaka M, Toouli J. High definition digital video links for surgical training. Success and Faliures in Telehealth ---Conference proceedings. 2006.
18. Acosta E, Temkin B. Dynamic generation of surgery specific simulators -- a feasibility study. Stud Health Technol Inform. 2005;111:1-7.
19. Hamilton EC, Scott DJ, Kapoor A, Nwariaku F, Bergen PC, Rege RV, et al. Improving operative performance using a laparoscopic hernia simulator. Am J Surg. 2001 Dec;182(6):725-8.
20. Grober ED, Hamstra SJ, Wanzel KR, Reznick RK, Matsumoto ED, Sidhu RS, et al. The educational impact of bench model fidelity on the acquisition of technical skill: the use of clinically relevant outcome measures. Ann Surg. 2004 Aug;240(2):374-81.
21. Reichel JL, Peirson RP, Berg D. Teaching and evaluation of surgical skills in dermatology: results of a survey. Arch Dermatol. 2004 Nov;140(11):1365-9.
22. Pandey V, Wolfe JH, Moorthy K, Munz Y, Jackson MJ, Darzi AW. Technical skills continue to improve beyond surgical training. J Vasc Surg. 2006 Mar;43(3):539-45.
23. Aggarwal R, Grantcharov T, Moorthy K, Hance J, Darzi A. A competency-based virtual reality training curriculum for the acquisition of laparoscopic psychomotor skill. Am J Surg. 2006 Jan;191(1):128-33.
24. Aggarwal R CJ. Virtual Reality Simulation Training can Improve Inexperienced Surgeons' Endovascular Skills European Journal of Vascular and Endovascular Surgery 2006;31(6):588-93.
25. Gold JP, Verrier EA, Olinger GN, Orringer MB, Kron IL. Development of a CD-ROM Internet Hybrid: A new thoracic surgery curriculum. Annals of Thoracic Surgery. 2002;74(5):1741.
26. Gold J BW, Fullerton D, Mathisen D, Olinger G, Orringer M, Verrier E. Successful Implementation of a novel internet hybrid surgery curriculum. Annals of surgery. 2004;240(3).
27. Gold J. Invited commentary. Ann Thorac Surg. 2006 May;81(5):1766.
28. Park A, Witzke D, Donnelly M. Ongoing deficits in resident training for minimally invasive surgery. J Gastrointest Surg. 2002 May-Jun;6(3):501-7; discussion 7-9.
29. Lawrence PF, Alexander RH, Bell RM, Folse R, Guy JR, Haynes JL, et al. Determining the content of a surgical curriculum. Surgery. 1983 Aug;94(2):309-17.
30. Ali MR, Mowery Y, Kaplan B, DeMaria EJ. Training the novice in laparoscopy. More challenge is better. Surg Endosc. 2002 Dec;16(12):1732-6.

31. Boyd WD, Kodera K, Stahl KD, Rayman R. Current status and future directions in computer-enhanced video- and robotic-assisted coronary bypass surgery. Semin Thorac Cardiovasc Surg. 2002 Jan;14(1):101-9.
32. Zbar RI, Otake LR, Miller MJ, Persing JA, Dingman DL. Web-based medicine as a means to establish centers of surgical excellence in the developing world. Plast Reconstr Surg. 2001 Aug;108(2):460-5.
33. Unsworth CA. Using a head-mounted video camera to study clinical reasoning. Am J Occup Ther. 2001 Sep-Oct;55(5):582-8.
34. Malcolm C, Irby, D., Reznick, R., MacRae, H. Teaching Surgical Skills — Changes in the Wind. New England Journal of Medicine. 2006;355:2664-9.
35. Rosenberg M. Beyond E-Learning. U.S.A.: Wiley and Sons: Pfeiffer; 2006.
36. Rogers DA. Ethical and educational considerations in minimally invasive surgery training for practicing surgeons. Semin Laparosc Surg. 2002 Dec;9(4):206-11.
37. Kaplan B & Shaw NT. People, Organizational, and Social Issues: Evaluation as an exemplar. U.S.A: Yearbook of Medical Informatics; 2002.
38. Pololi L CP, Knight S, Carr P. A study of the relational aspects of the culture of academic medicine. Acad Med 2009 Jan;84(1):106-14(Jan, 2009).
39. Shollen SL BC, Finstad DA, Taylor AL. Organizational climate and family life: how these factors affect the status of women faculty at one medical school. Acad Med 2009 84(1):87-94(Jan 2009).
40. Kneebone R, ApSimon D. Surgical skills training: simulation and multimedia combined. Med Educ. 2001 Sep;35(9):909-15.
41. Kneebone RL, Scott W, Darzi A, Horrocks M. Simulation and clinical practice: strengthening the relationship. Med Educ. 2004 Oct;38(10):1095-102.
42. Bernardo TM, Malinowski RP. Progress in the capture, manipulation, and delivery of medical media and its impact on education, clinical care, and research. J Vet Med Educ. 2005 Spring;32(1):21-30.
43. Goldberg MA, Sharman Z, Bell B, Ho K, Patil N. E-health and the Universitas. J Telemed Telecare. 2005;11(5):230-3.
44. Kaufnman J, Dawson. S., editor. The imperative for medical simulation. IEEE; 1998.
45. McArthur JR. The development and use of video discs in medical education. J Clin Comput. 1985;13(5):145-9.
46. Lillehaug SI, Lajoie SP. AI in medical education--another grand challenge for medical informatics. Artif Intell Med. 1998 Mar;12(3):197-225.

47. Letterie GS, Letterie GS. Medical education as a science: The quality of evidence for computer-assisted instruction. American Journal of Obstetrics and Gynecology. 2003;188(3):849.
48. White Mea. Commitment to change instrument enhances program planning, implementation and evaluation. The Journal of Continuing Medical Education in the Health Professions. 2004;24:153-62.
49. Wutoh R, Boren SA, Balas EA. eLearning: a review of Internet-based continuing medical education. [Review] [28 refs]. Journal of Continuing Education in the Health Professions. 2004;24(1):20.
50. Mekasha;. Assessment methods in medical education.
PMID: 15884279 [PubMed - indexed for MEDLINE]. Ethiop Med J 2004 Jan;42(1):63-71 2004; Jan;42(1):63-71. :63-71. .
51. Aboud E, Al-Mefty O, Yasargil MG. New laboratory model for neurosurgical training that simulates live surgery. J Neurosurg. 2002 Dec;97(6):1367-72.
52. Lehmann KS, Ritz JP, Maass H, Cakmak HK, Kuehnapfel UG, Germer CT, et al. A prospective randomized study to test the transfer of basic psychomotor skills from virtual reality to physical reality in a comparable training setting. Ann Surg. 2005 Mar;241(3):442-9.
53. McNatt SS, Smith CD. A computer-based laparoscopic skills assessment device differentiates experienced from novice laparoscopic surgeons. Surg Endosc. 2001 Oct;15(10):1085-9.
54. Paisley AM, Baldwin PJ, Paterson-Brown S. Validity of surgical simulation for the assessment of operative skill. Br J Surg. 2001 Nov;88(11):1525-32.
55. Hennessey JG, Fishman EK, Ney DR. Digital video applications in radiologic education: theory, technique, and applications. Journal of Digital Imaging. 1994 May;7(2):85.
56. Escott EJ, Rubinstein D. Free DICOM image viewing and processing software for your desktop computer: what's available and what it can do for you. Radiographics. 2003 Sep-Oct;23(5):1341-57.
57. Patel VL, Arocha JF, Leccisi MS. Impact of undergraduate medical training on housestaff problem-solving performance: implications for problem-based curricula. J Dent Educ. 2001 Nov;65(11):1199-218.
58. Falzone RL, Hall S, Beresin EV. How and why for the camera-shy: using digital video in psychiatry. Child Adolesc Psychiatr Clin N Am. 2005 Jul;14(3):603-12, xi.
59. Jaworski CA. Advances in emergent airway management. Curr Sports Med Rep. 2002 Jun;1(3):133-40.
60. Cherian MN, Noel L, Buyanjargal Y, Salik G. Essential emergency surgical, procedures in resource-limited facilities: a WHO workshop in Mongolia. World Hospitals & Health Services. 2004;40(4):24.

61. Kesavadas T, Srimathveeravalli G, Arulesan V. Parametric modeling and simulation of trocar insertion. Stud Health Technol Inform. 2006;119:252-4.
62. Magill MK. Interactive video in family medicine. Family medicine. 1986 Jul-Aug;18(4):226.
63. Nagendran S. Spooner R. Moores D. Humphries P. Schipper S. Hebert M. The Design and Implementation of a Digital Library of Procedures and Examination Skills for Family Medicine. Proceedings of the 11th International symposium for health information management research. 2006.
64. Rodney WM, Felmar E, Auslander M. AAFP--ASGE conjoint course on flexible sigmoidoscopy. Fam Pract Res J. 1986 Summer;5(4):209-15.
65. Lee E, Kim HK, Kim I. Anatomic pathology image capture using a consumer-type digital camera. Am J Surg Pathol. 2000 Jul;24(7):1034-5.
66. Duval da Silva V. Digital video microscopy in pathology. Pathologica. 1999 Apr;91(2):124-7.
67. Marchevsky AM RA, Baillie S. . Self-instructional "virtual pathology" laboratories using web-based technology enhance medical school teaching of pathology. Human Pathology 2003;34(5)::423-9. .
68. Perris A, Pateras K, Rizopoulos D, Skourlas C, Maris T. A CD-ROM prototype of a multimedia-based interactive tool and guide, to perform quality control tests for the computed tomography scanners. Medical Informatics. 1996 Apr-Jun;21(2):169.
69. Desrosiers M. The multimedia CD ROM: an innovative teaching tool for endoscopic sinus surgery. J Laparoendosc Adv Surg Tech A. 1998 Aug;8(4):219-24.
70. Kallinowski F, Mehrabi A, Schwarzer H, Herfarth C. Development of a multimedia CD-ROM series for improving surgical education and continuing education. Langenbecks Archiv fur Chirurgie - Supplement - Kongressband. 1998;115:885.
71. Cheung ST, Davies RF, Smith K, Marsh R, Sherrard H, Keon WJ. The Ottawa telehealth project. Telemedicine Journal. 1998;4(3):259.
72. Saxe DM, Foulds RA. Robust region of interest coding for improved sign language telecommunication. IEEE Trans Inf Technol Biomed. 2002 Dec;6(4):310-6.
73. Cafazzo JA, Theal JJ, Medad I, Rossos PG. Digital video for the documentation of colonoscopy. Gastrointest Endosc. 2004 Oct;60(4):580-4.
74. Saari JM, Kerola MT, Broas M, Saari KM. Hand-held digital video-camera for eye examination and follow-up. J Telemed Telecare. 2002;8(4):237-40.
75. Hohn H, Esser W, Hamm H, Albert J. Image archives, audio- and video-sequences for teleteaching. Curr Probl Dermatol. 2003;32:191-4.

76. Scheeres DE, Mellinger JD, Brasser BA, Davis AT. Animate advanced laparoscopic courses improve resident operative performance. Am J Surg. 2004 Aug;188(2):157-60.
77. Hermann M. 3-dimensional computer animation--a new medium for supporting patient education before surgery. Acceptance and assessment of patients based on a prospective randomized study--picture versus text]. Chirurg. 2002 May;73(5):500-7.
78. Wootton R. Successes and faliures in telehealth-6. Conference Proceedings. [Conference Proceedings]. 2006.
79. Romer DJ, Suster S. Use of virtual microscopy for didactic live-audience presentation in anatomic pathology. Ann Diagn Pathol. 2003 Feb;7(1):67-72.
80. Sharland MR. Digital imaging for the general dental practitioner: 2. Intra-oral imaging. Dent Update. 2004 Jul-Aug;31(6):328-32.
81. Gandsas A, McIntire K, Montgomery K, Bumgardner C, Rice L. The personal digital assistant (PDA) as a tool for telementoring endoscopic procedures. Stud Health Technol Inform. 2004;98:99-103.
82. Willaing I, Ladelund S. Nurse counseling of patients with an overconsumption of alcohol. J Nurs Scholarsh. 2005;37(1):30-5.
83. Shah J, Darzi A. Virtual reality flexible cystoscopy: a validation study. BJU Int. 2002 Dec;90(9):828-32.
84. Schijven MP, Jakimowicz JJ, Carter FJ. How to select aspirant laparoscopic surgical trainees: establishing concurrent validity comparing Xitact LS500 index performance scores with standardized psychomotor aptitude test battery scores. J Surg Res. 2004 Sep;121(1):112-9.
85. Geueke M, Stausberg J. A meta-data-based learning resource server for medicine. Comput Methods Programs Biomed. 2003 Nov;72(3):197-208.
86. Kallinowski F, Mehrabi A, Gluckstein C, Benner A, Lindinger M, Hashemi B, et al. Computer-based training--a new method in surgical education and continuing education. Chirurg. 1997 Apr;68(4):433-8.
87. Bernardo V, Ramos MP, Plapler H, De Figueiredo LF, Nader HB, Ancao MS, et al. Web-based learning in undergraduate medical education: development and assessment of an online course on experimental surgery. International journal of medical informatics. 2004 Sep;73(9-10):731.
88. Schultze-Mosgau S, Zielinski T, Lochner J. Web-based, virtual course units as a didactic concept for medical teaching. Med Teach. 2004 Jun;26(4):336-42.
89. Slater SG, Sorkin HL. Telemedicine. The impact of the Web & e-health management. Caring. 2001 May;20(5):34-7.
90. Sparacia G, Tartamella M, Finazzo M, Bartolotta T, Brancatelli G, Banco A, et al. Server World-Wide Web on the Internet for the provision of clinical cases and digital radiologic images for training and continuing education in radiology. Radiologia Medica. 1997 Jun;93(6):743.

91. Webber WB, Summers AN, Rinehart GC. Computer-based multimedia in plastic surgery education. Plast Reconstr Surg. 1994 May;93(6):1290-300.
92. Thurmond VA. Defining interaction and strategies to enhance interactions in Web-based courses. . Nurse educator. 2003 Sep-Oct;28(5):237.
93. Shaffer K, Small JE. Blended learning in medical education: use of an integrated approach with web-based small group modules and didactic instruction for teaching radiologic anatomy. Acad Radiol. 2004 Sep;11(9):1059-70.
94. Burgess RC. Design and evolution of a system for long-term electroencephalographic and video monitoring of epilepsy patients. Methods. 2001 Oct;25(2):231-48.
95. Dev P, Rindfleisch TC, Kush SJ, Stringer JR. An analysis of technology usage for streaming digital video in support of a preclinical curriculum. Proc AMIA Symp. 2000:180-4.
96. Kawaida M, Fukuda H, Kohno N. Video-assisted rigid endoscopic laryngosurgery: application to cases with difficult laryngeal exposure. J Voice. 2001 Jun;15(2):305-12.
97. Kalu PU, Atkins J, Baker D, Green CJ, Butler PE. How do we assess microsurgical skill? Microsurgery. 2005;25(1):25-9.
98. Goff. B ML, Gretchen L VanBlaricom A Oelschlager A, Lee D, Galakatos A Matthew D, Nielsen P.. . Assessment of resident surgical skills: Is testing feasible? . American Journal of Obstetrics and Gynecology 2005;192(4):1331-8.
99. Bann SD, Datta VK, Khan MS, Ridgway PF, Darzi AW. Attitudes towards skills examinations for basic surgical trainees. Int J Clin Pract. 2005 Jan;59(1):107-13.
100. Vogt VY, Givens VM, Keathley CA, Lipscomb GH, Summitt RL, Jr. Is a resident's score on a videotaped objective structured assessment of technical skills affected by revealing the resident's identity? Am J Obstet Gynecol. 2003 Sep;189(3):688-91.
101. Beard JD, Jolly BC, Newble DI, Thomas WE, Donnelly J, Southgate LJ. Assessing the technical skills of surgical trainees. Br J Surg. 2005 Jun;92(6):778-82.
102. Desrosiers M, Craig P. Improved video documentation of endoscopic sinus surgery made possible with desktop digital video. Am J Rhinol. 1997 May-Jun;11(3):197-202.
103. CD ROM: what is it? What can it do for me? Nurs Educ Microworld. 1988 Apr-May;2(4):1.
104. Keerl R, Weber R. Surgical continuing education with multi-media techniques exemplified by endonasal micro-endoscopic pan-sinus operation. Laryngo- rhino- otologie. 1995 Jun;74(6):361.
105. Rosser JC, Herman B, Risucci DA, Murayama M, Rosser LE, Merrell RC. Effectiveness of a CD-ROM multimedia tutorial in transferring cognitive

knowledge essential for laparoscopic skill training. American Journal of Surgery. 2000 Apr;179(4):320.
106. French JG, Yu M, Samant R. The development and production of radiotherapy patient education videos using computer-based digital imagery. Int J Radiat Oncol Biol Phys. 1998 May 1;41(2):485.
107. Gandsas A, McIntire K, George IM, Witzke W, Hoskins JD, Park A. Wireless live streaming video of laparoscopic surgery: a bandwidth analysis for handheld computers. Studies in health technology and informatics. 2002;85:150.
108. Bartels H, Dikkers FG, van der Wal JE, Lokhorst HM, Hazenberg BP. Laryngeal amyloidosis: localized versus systemic disease and update on diagnosis and therapy. Ann Otol Rhinol Laryngol. 2004 Sep;113(9):741-8.
109. Boudier T, Shotton DM. Video on the Internet: An introduction to the digital encoding, compression, and transmission of moving image data. J Struct Biol. 1999 Apr-May;125(2-3):133-55.
110. Spicer MA, Apuzzo ML. Virtual reality surgery: neurosurgery and the contemporary landscap. Neurosurgery. 2003 discussion 496-7; Mar;52(3):489.
111. Madan AK, Frantzides CT, Sasso LM. Laparoscopic baseline ability assessment by virtual reality. J Laparoendosc Adv Surg Tech A. 2005 Feb;15(1):13-7.
112. Tuggy ML. Virtual reality flexible sigmoidoscopy simulator training: impact on resident performance. J Am Board Fam Pract. 1998 Nov-Dec;11(6):426-33.
113. Ro CY, Toumpoulis IK, Ashton RC, Jr., Jebara T, Schulman C, Todd GJ, et al. The LapSim: a learning environment for both experts and novices. Stud Health Technol Inform. 2005;111:414-7.
114. McDougall EM, Corica FA, Boker JR, Sala LG, Stoliar G, Borin JF, et al. Construct validity testing of a laparoscopic surgical simulator. J Am Coll Surg. 2006 May;202(5):779-87.
115. Sweet R, Porter J, Oppenheimer P, Hendrickson D, Gupta A, Weghorst S. Simulation of bleeding in endoscopic procedures using virtual reality. J Endourol. 2002 Sep;16(7):451-5.
116. Tsai MD, Hsieh MS, Jou SB. Virtual reality orthopedic surgery simulator. Comput Biol Med. 2001 Sep;31(5):333-51.
117. Pham T, Roland L, Benson KA, Webster RW, Gallagher AG, Haluck RS. Smart tutor: a pilot study of a novel adaptive simulation environment. Stud Health Technol Inform. 2005;111:385-9.
118. Cai YY, Chui CK, Ye XZ, Fan Z, Anderson JH. Tactile VR for hand-eye coordination in simulated PTCA. Comput Biol Med. 2006 Feb;36(2):167-80.
119. Marchack CB. Guidelines for digital scientific presentations. J Prosthet Dent. 2002 Dec;88(6):649-53.

120. Niamtu J, 3rd. Techno pearls for digital image management. Dermatol Surg. 2002 Oct;28(10):946-50.
121. Benz C. Digital photography: exposures, editing images, and presentation. Int J Comput Dent. 2003 Jul;6(3):249-81.
122. Blevins NH, Lustig LR. Current digital imaging for the otolaryngologist. Curr Opin Otolaryngol Head Neck Surg. 2003 Jun;11(3):166-72.
123. Sadiq Z, Moss C. Digitisation of pathology slides. Br J Oral Maxillofac Surg. 2002 Aug;40(4):348-9.
124. Entwistle A. Sharing digital micrographs and other data files between computers. Biotech Histochem. 2004 Jun-Aug;79(3-4):111-20.
125. Ingram K, Bunta F, Ingram D. Digital data collection and analysis: application for clinical practice. Lang Speech Hear Serv Sch. 2004 Apr;35(2):112-21.
126. Kumar AS, Pal H. Digital video recording of cardiac surgical procedures. Ann Thorac Surg. 2004 Mar;77(3):1063-5.
127. Kingsnorth A, Vranch A, Campbell J. Training for surgeons using digital satellite television and videoconferencing. J Telemed Telecare. 2000;6 Suppl 1:S29-31.
128. Johnson D, Johnson M. Digital video. Clin Orthop Relat Res. 2004 Apr(421):17-24.
129. Iskander DR, Collins MJ, Mioschek S, Trunk M. Automatic pupillometry from digital images. IEEE Trans Biomed Eng. 2004 Sep;51(9):1619-27.
130. Kanani M, Kocyildirim E, Cohen G, Bentham K, Elliott MJ. Method and value of digital recording of operations for congenital heart disease. Ann Thorac Surg. 2004 Dec;78(6):2146-9; discussion 9.
131. Lim MW, Burt G, Rutter SV. Use of three-dimensional animation for regional anaesthesia teaching: application to interscalene brachial plexus blockade. Br J Anaesth. 2005 Mar;94(3):372-7.
132. Satava RM. Virtual reality, telesurgery, and the new world order of medicine. J Image Guid Surg. 1995;1(1):12-6.
133. Malassagne B, Mutter D, Leroy J, Smith M, Soler L, Marescaux J. Teleeducation in surgery: European Institute for Telesurgery experience. World J Surg. 2001 Nov;25(11):1490-4.
134. Rosen J, Brown JD, Barreca M, Chang L, Hannaford B, Sinanan M. The Blue DRAGON--a system for monitoring the kinematics and the dynamics of endoscopic tools in minimally invasive surgery for objective laparoscopic skill assessment. Stud Health Technol Inform. 2002;85:412-8.
135. Jao CS, Hier DB, Brint SU. Converting laserdisc video to digital video: a demonstration project using brain animations. J Am Med Inform Assoc. 1995 Jan-Feb;2(1):1-3.

136. McEachen JC, Cusack TJ, McEachen JC. A model for a PC-based, universal-format, multimedia digitization system: moving beyond the scanner. Acad Radiol. 2003 Aug;10(8):914-8.
137. Lefer W, Jobard B, Leduc C. High-quality animation of 2D steady vector fields. IEEE Trans Vis Comput Graph. 2004 Jan-Feb;10(1):2-14.
138. Herrell SD, Smith JA, Jr. Robotic-assisted laparoscopic prostatectomy: what is the learning curve? Urology. 2005 Nov;66(5 Suppl):105-7.
139. Panait L, Doarn CR, Merrell RC. Applications of robotics in surgery. Chirurgia (Bucur). 2002 Nov-Dec;97(6):549-55.
140. Chang L, Satava RM, Pellegrini CA, Sinanan MN. Robotic surgery: identifying the learning curve through objective measurement of skill. Surg Endosc. 2003 Nov;17(11):1744-8.
141. Dobrosavljevic S, Welter R. Telemediana: Telesurgery and telemedicine by satellite and the internet. Proceedings of SPIE - The International Society for Optical Engineering. 2002;4912:29.
142. Hudson JN. Computer-aided learning in the real world of medical education: does the quality of interaction with the computer affect student learning? Med Educ. 2004 Aug;38(8):887-95.
143. Sultana CJ, Levy J, Rogers R, Jr. Video vs. CD-ROM for teaching pelvic anatomy to third-year medical students. A comparison. Journal of Reproductive Medicine. 2001 Jul;46(7):675.
144. http://www.davincisurgery.com/cardiothoracic/. da Vinci robotic system. 2010 [updated 2010; cited]; Available from.
145. Boehm DH, Arnold MB, Detter C, Reichenspurner HC. Incorporating robotics into an open-heart program. Surg Clin North Am. 2003 Dec;83(6):1369-80.
146. Taylor GW. Developing technology for surgery in the UK: a multidisciplinary meeting of engineers and surgeons. Int J Med Robot. 2007 Mar;3:30-4.
147. Casebeer LL, Strasser SM, Spettell CM, Wall TC, Weissman N, Ray MN, et al. Designing tailored Web-based instruction to improve practicing physicians' preventive practices. J Med Internet Res. 2003 Jul-Sep;5(3):e20.
148. Chung SY, Landsittel D, Chon CH, Ng CS, Fuchs GJ. Laparoscopic skills training using a webcam trainer. J Urol. 2005 Jan;173(1):180-3.
149. Corl FM, Garland MR, Lawler LP, Fishman EK. A five-step approach to digital image manipulation for the radiologist. Radiographics. 2002 Jul-Aug;22(4):981-92.
150. Burke RP. Minimally invasive pediatric cardiac surgery. Current Opinion in Pediatrics. 1998;10(5):527.
151. Aggarwal R, Moorthy K, Darzi A. Laparoscopic skills training and assessment. Br J Surg. 2004 Dec;91(12):1549-58.

152. Apple SL, Schmidt JH. Technique for neurosurgically relevant CT image transfers using inexpensive video digital technology. Surg Neurol. 2000 May;53(5):411-6.
153. Backstein D, Agnidis Z, Sadhu R, MacRae H. Effectiveness of repeated video feedback in the acquisition of a surgical technical skill. Can J Surg. 2005 Jun;48(3):195-200.
154. Crawford FA, Jr. Thoracic surgery education--past, present, and future. Ann Thorac Surg. 2005 Jun;79(6):S2232-7.
155. Darzi A, Mackay S. Assessment of surgical competence. Qual Health Care. 2001 Dec;10 Suppl 2:ii64-9.
156. Fried MP, Satava R, Weghorst S, Gallagher AG, Sasaki C, Ross D, et al. Identifying and reducing errors with surgical simulation. Qual Saf Health Care. 2004 Oct;13 Suppl 1:i19-26.
157. Hance J AR, Stanbridge R, Blauth C, Munz Y, Darzi A, Pepper J. Objective assesment of technical skills in cardiac surgery. European Journal of Cardio-thoracic Surgery. 2005;28:157-62.
158. Hansen DD, Lavoie J, Burrows FA. Video-assisted thoracoscopic surgery for the treatment of congenital cardiac defects in the pediatric population. Anesthesia and Analgesia. 1996;82(3):563.
159. Hiatt JR, Shabot MM, Phillips EH, Haines RF, Grant TL. Telesurgery. Acceptability of compressed video for remote surgical proctoring. Arch Surg. 1996 Apr;131(4):396-401.
160. Kothari SN, Kaplan BJ, DeMaria EJ, Broderick TJ, Merrell RC. Training in laparoscopic suturing skills using a new computer-based virtual reality simulator (MIST-VR) provides results comparable to those with an established pelvic trainer system. J Laparoendosc Adv Surg Tech A. 2002 Jun;12(3):167-73.
161. Mehrabi A, Gluckstein C, Benner A, Hashemi B, Herfarth C, Kallinowski F. A new way for surgical education--development and evaluation of a computer-based training module. Comput Biol Med. 2000 Mar;30(2):97-109.
162. Qayumi AK, Qayumi, T. Computer-Assisted Learning: cyberPatient- A step in the future of surgical education. Journal of Investigative Surgery. 1999;12:307-317:307-17.
163. Rassweiler J, Binder J, Frede T. Robotic and telesurgery: will they change our future?. Current opinion in urology. 2001 May;11(3):309.
164. Seymour NGA, Roman SA, O'Brien MK, Bansal VK, Andersen DK, et al. Virtual reality traning improves operating room performance: resultd of a randomized, double-blinded study. Annals of surgery. 2002;236:458-64(236:458-64).
165. Wang P, Becker AA, Jones IA, Glover AT, Benford SD, Greenhalgh CM, et al. A virtual reality surgery simulation of cutting and retraction in

neurosurgery with force-feedback. Comput Methods Programs Biomed. 2006 Oct;84(1):11-8.
166. Yc Goha K, editor. Virtual reality applications in neurosurgery. Conf Proc IEEE Eng Med Biol Soc; 2005.
167. Swanstrom LL, Fried GM, Hoffman KI, Soper NJ. Beta test results of a new system assessing competence in laparoscopic surgery. J Am Coll Surg. 2006 Jan;202(1):62-9.
168. Madan AK, Frantzides CT, Park WC, Tebbit CL, Kumari NV, O'Leary PJ. Predicting baseline laparoscopic surgery skills. Surg Endosc. 2005 Jan;19(1):101-4.
169. Keehner MM, Tendick F, Meng MV, Anwar HP, Hegarty M, Stoller ML, et al. Spatial ability, experience, and skill in laparoscopic surgery. Am J Surg. 2004 Jul;188(1):71-5.
170. Fried GM, Feldman LS, Vassiliou MC, Fraser SA, Stanbridge D, Ghitulescu G, et al. Proving the value of simulation in laparoscopic surgery. Ann Surg. 2004 Sep;240(3):518-25; discussion 25-8.
171. Gettman MT, Kondraske GV, Traxer O, Ogan K, Napper C, Jones DB, et al. Assessment of basic human performance resources predicts operative performance of laparoscopic surgery. J Am Coll Surg. 2003 Sep;197(3):489-96.
172. Law B, Atkins MS, Lomax AJ, Wilson JG. Eye trackers in a virtual laparoscopic training environment. Stud Health Technol Inform. 2003;94:184-6.
173. Odell EW, Francis CA, Eaton KA, Reynolds PA, Mason RD. A study of videoconferencing for postgraduate continuing education in dentistry in the UK--the teachers' view. European Journal of Dental Education. 2001 Aug;5(3):113.
174. Risucci D, Geiss A, Gellman L, Pinard B, Rosser J. Surgeon-specific factors in the acquisition of laparoscopic surgical skills. Am J Surg. 2001 Apr;181(4):289-93.
175. Stolzenburg JU, Schwaibold H, Bhanot SM, Rabenalt R, Do M, Truss M, et al. Modular surgical training for endoscopic extraperitoneal radical prostatectomy. BJU Int. 2005 Nov;96(7):1022-7.
176. Woodrum DT, Andreatta PB, Yellamanchilli RK, Feryus L, Gauger PG, Minter RM. Construct validity of the LapSim laparoscopic surgical simulator. Am J Surg. 2006 Jan;191(1):28-32.
177. Gallagher AG, Lederman AB, McGlade K, Satava RM, Smith CD. Discriminative validity of the Minimally Invasive Surgical Trainer in Virtual Reality (MIST-VR) using criteria levels based on expert performance. Surg Endosc. 2004 Apr;18(4):660-5.
178. Klein Kranenbarg E, van de Velde CJ. Surgical trials in oncology. the importance of quality control in the TME trial. Eur J Cancer. 2002 May;38(7):937-42.

179. Kubler C, Bauer L, Heinze P, Raczkowsky J, Worn H. Realtime textured 3D-models for medical applications. Stud Health Technol Inform. 2002;85:247-51.
180. Pavlovich RI, Vazquez-Vela G, Pardinas JL, Bustos Villarreal JM, Rico EC, de la Mora Behar G. Basic science in digital imaging: digital dynamic radiography, multimedia, and their potential uses for orthopaedics and arthroscopic surgery. Arthroscopy. 2002 Jul-Aug;18(6):639-47.
181. Katzman GL. CD/DVD technology. Semin Ultrasound CT MR. 2003 Dec;24(6):410-9.
182. Molander B, Grondahl HG, Ekestubbe A. Quality of film-based and digital panoramic radiography. Dentomaxillofac Radiol. 2004 Jan;33(1):32-6.
183. Zhang R, Yamauchi K, Nonogawa M, Ikeda M, Zhang W, Huang D. A telemedicine system for collaborative work on radiographic coronary video-images. J Telemed Telecare. 2004;10(3):152-5.
184. Rosen AL, Hausman M. Digital imaging and video: principles and applications. J Am Acad Orthop Surg. 2003 Nov-Dec;11(6):373-9.
185. Riley RS, Ben-Ezra JM, Massey D, Slyter RL, Romagnoli G. Digital photography: a primer for pathologists. J Clin Lab Anal. 2004;18(2):91-128.
186. Herr HW. Surgical factors in the treatment of superficial and invasive bladder cancer. Urol Clin North Am. 2005 May;32(2):157-64.
187. Keshtgar MR, Chicken DW, Waddington WA, Raven W, Ell PJ. A training simulator for sentinel node biopsy in breast cancer: a new standard. Eur J Surg Oncol. 2005 Mar;31(2):134-40.
188. Mao C. Teaching residents humanistic skills in a colposcopy clinic. Acad Med. 2002 Jul;77(7):742.
189. Holman JR, Marshall RC, Jordan B, Vogelman L. Technical competency in flexible sigmoidoscopy. J Am Board Fam Pract. 2001 Nov-Dec;14(6):424-9.
190. Nagendran S SGR, Moores D., Humphries P., Hebert M. , editor. Digital Library of procedures and examination skills for family practice; . North American Primary Care Research Group- NAPCRG; 2004.
191. Harris CH, Smith RS, Helmer SD, Gorecki JP, Rody RB. Placement of intracranial pressure monitors by non-neurosurgeons. Am Surg. 2002 Sep;68(9):787-90.
192. Mahadevan SV, Gisondi MA, Sovndal SS, Gilbert GH. Emergency department orientation utilizing web-based streaming video. Acad Emerg Med. 2004 Aug;11(8):848-52.
193. Lambert MJ, Villa M. Gynecologic ultrasound in emergency medicine. Emerg Med Clin North Am. 2004 Aug;22(3):683-96.
194. Patel VL, Kaufman DR, Arocha JF. Emerging paradigms of cognition in medical decision-making. Journal of Biomedical Informatics. 2002 Feb;35(1):52.

195. Whitson B, Hoang, C., Jie, T. Technology -Enhanced interactive surgical education. Journal of Surgical Research. 2006;136(1):13-8.
196. Kaufmann CR. Computers in surgical education and the operating room. Ann Chir Gynaecol. 2001;90(2):141-6.
197. Vercellotti T. Technological characteristics and clinical indications of piezoelectric bone surgery. Minerva Stomatol. 2004 May;53(5):207-14.
198. van Bergen P, Kunert W, Buess GF. The effect of high-definition imaging on surgical task efficiency in minimally invasive surgery: an experimental comparison between three-dimensional imaging and direct vision through a stereoscopic TEM rectoscope. Surg Endosc. 2000 Jan;14(1):71-4.
199. Katz R, Hoznek A, Salomon L, Antiphon P, de la Taille A, Abbou CC. Skill assessment of urological laparoscopic surgeons: can criterion levels of surgical performance be determined using the pelvic box trainer? Eur Urol. 2005 Apr;47(4):482-7.
200. Gunther SB, Soto GE, Colman WW. Interactive computer simulations of knee-replacement surgery. Acad Med. 2002 Jul;77(7):753-4.
201. Backstein D, Agnidis Z, Regehr G, Reznick R. The effectiveness of video feedback in the acquisition of orthopedic technical skills. Am J Surg. 2004 Mar;187(3):427-32.
202. Torkington J, Smith SG, Rees BI, Darzi A. Skill transfer from virtual reality to a real laparoscopic task. Surg Endosc. 2001 Oct;15(10):1076-9.
203. Hsu JH, Younan D, Pandalai S, Gillespie BT, Jain RA, Schippert DW, et al. Use of computer simulation for determining endovascular skill levels in a carotid stenting model. J Vasc Surg. 2004 Dec;40(6):1118-25.
204. Ota D, Loftin B, Saito T, Lea R, Keller J. Virtual reality in surgical education. Computers in Biology and Medicine. 1995;25(2):127.
205. Madan AK, Frantzides CT, Shervin N, Tebbit CL. Assessment of individual hand performance in box trainers compared to virtual reality trainers. Am Surg. 2003 Dec;69(12):1112-4.
206. Munver R, Del Pizzo JJ, Sosa RE, Poppas DP. Minimally invasive surgical management of ureteropelvic junction obstruction: laparoscopic and robot-assisted laparoscopic pyeloplasty. J Long Term Eff Med Implants. 2003;13(5):367-84.
207. Grunwald T, Krummel T, Sherman R. Advanced technologies in plastic surgery: how new innovations can improve our training and practice. Plastic & Reconstructive Surgery. 2004 Nov;114(6):1556.
208. Smarrito S, Mitrofanoff M, Haddad R, Pavy B. Do we need a chart of quality for websites related to cosmetic surgery? Ann Chir Plast Esthet. 2003 Aug;48(4):222-7.
209. Houkin K, Kuroda S, Abe H. Operative record using intraoperative digital data in neurosurgery. Acta Neurochir (Wien). 2000;142(8):913-9.

210. Hubert J, Feuillu B, Beis JM, Coissard A, Mangin P, Andre JM. Laparoscopic robotic-assisted ileal conduit urinary diversion in a quadriplegic woman. Urology. 2003 Dec;62(6):1121.
211. Challacombe BJ, Khan MS, Murphy D, Dasgupta P. The history of robotics in urology. World J Urol. 2006 Jun;24(2):120-7.
212. Wierzbicki M, Drangova M, Guiraudon G, Peters T. Validation of dynamic heart models obtained using non-linear registration for virtual reality training, planning, and guidance of minimally invasive cardiac surgeries. Med Image Anal. 2004 Sep;8(3):387-401.
213. Autschbach R, Onnasch JF, Falk V, Walther T, Kruger M, Schilling LO, et al. The Leipzig experience with robotic valve surgery. J Card Surg. 2000 Jan-Feb;15(1):82-7.
214. Gerosa G, di Marco F, Bianco R, Vendramin I, Casarotto D. First Italian robot-enhanced coronary bypass. Ital Heart J. 2004 Jun;5(6):475-8.
215. Cuschieri A. Laparoscopic surgery in Europe. Where are we going? Cir Esp. 2006 Jan;79(1):10-21.
216. Nakayama H, Masuda H, Fukuzawa M. Recording of surgery with two crane-type tripods and video cameras. Int Surg. 2004 Oct-Dec;89(4):217-20.
217. Chan KY, Rohaizak M, Sukumar N, Shaharuddin S, Jasmi AY. Inguinal hernia repair by surgical trainees at a Malaysian teaching hospital. Asian J Surg. 2004 Oct;27(4):306-12.
218. Ackerman MJ. Optical technology: making the simulator portable. J Biocommun. 1992;19(3):22-4.
219. http://www.ucalgary.ca/news/april2007/neuroarm [database on the Internet]. University of Calgary. 2007 [cited.
220. Baskett RJ, Buth KJ, Legare JF, Hassan A, Friesen CH, Hirsch GM, et al. Is it safe to train residents to perform cardiac surgery? Ann Thorac Surg. 2002 Oct;74(4):1043-8; discussion 8-9.
221. CaRMS. PI. www.CaRMS.ca. www.CaRMS.ca; 2006 [updated 2006; cited]; Available from.
222. Silverstein SC. Medicine in the 21st century: preparing for a paradigm shift. J Investig Med. 1998 Oct;46(8):342-7.
223. Krelinger FaL, H. Foundation of Behavioral research(4thEdition). . 2000.
224. Mackay S, Datta V, Chang A, Shah J, Kneebone R, Darzi A. Multiple Objective Measures of Skill (MOMS): a new approach to the assessment of technical ability in surgical trainees. Ann Surg. 2003 Aug;238(2):291-300.
225. Goff BA, Lentz GM, Lee D, Fenner D, Morris J, Mandel LS. Development of a bench station objective structured assessment of technical skills. Obstet Gynecol. 2001 Sep;98(3):412-6.

226. Chiang YC, Lee FP, Peng CL, Lin CT. Measurement of tongue movement during vowels production with computer-assisted B-mode and M-mode ultrasonography. Otolaryngol Head Neck Surg. 2003 Jun;128(6):805-14.
227. Evans AW, Leeson RM, Newton John TR, Petrie A. The influence of self-deception and impression management upon self-assessment in oral surgery. Br Dent J. 2005 Jun 25;198(12):765-9; discussion 55.
228. Leeper-Majors K, Veale JR, Westbrook TS, Reed K. The effect of standardized patient feedback in teaching surgical residents informed consent: results of a pilot study. Curr Surg. 2003 Nov-Dec;60(6):615-22.
229. Datta V, Bann S, Beard J, Mandalia M, Darzi A. Comparison of bench test evaluations of surgical skill with live operating performance assessments. J Am Coll Surg. 2004 Oct;199(4):603-6.
230. Mackay S, Datta V, Mandalia M, Bassett P, Darzi A. Electromagnetic motion analysis in the assessment of surgical skill: Relationship between time and movement. ANZ J Surg. 2002 Sep;72(9):632-4.
231. Datta V, Mackay S, Mandalia M, Darzi A. The use of electromagnetic motion tracking analysis to objectively measure open surgical skill in the laboratory-based model. J Am Coll Surg. 2001 Nov;193(5):479-85.
232. Torkington J, Smith SG, Rees B, Darzi A. The role of the basic surgical skills course in the acquisition and retention of laparoscopic skill. Surg Endosc. 2001 Oct;15(10):1071-5.
233. Bird A, Wallis M. Nursing knowledge and assessment skills in the management of patients receiving analgesia via epidural infusion. J Adv Nurs. 2002 Dec;40(5):522-31.
234. Ferlitsch A, Glauninger P, Gupper A, Schillinger M, Haefner M, Gangl A, et al. Evaluation of a virtual endoscopy simulator for training in gastrointestinal endoscopy. Endoscopy. 2002 Sep;34(9):698-702.
235. Letterie GS. How virtual reality may enhance training in obstetrics and gynecology. Am J Obstet Gynecol. 2002 Sep;187(3 Suppl):S37-40.
236. Kohls-Gatzoulis JA, Regehr G, Hutchison C. Teaching cognitive skills improves learning in surgical skills courses: a blinded, prospective, randomized study. Can J Surg. 2004 Aug;47(4):277-83.
237. Velmahos GC, Toutouzas KG, Sillin LF, Chan L, Clark RE, Theodorou D, et al. Cognitive task analysis for teaching technical skills in an inanimate surgical skills laboratory. Am J Surg. 2004 Jan;187(1):114-9.
238. Kushniruk AW, Patel VL. Cognitive computer-based video analysis: its application in assessing the usability of medical systems. Medinfo. 1995;8 Pt 2:1566.
239. Patel VL, Kaufman DR, Arocha JA, Kushniruk AW. Bridging theory and practice: cognitive science and medical informatics. Medinfo. 1995;8 Pt 2:1278.

240. Kushniruk AW, Patel VL. Cognitive evaluation of decision making processes and assessment of information technology in medicine. IntJMedInform. 1998 Aug-Sep;51(2-3):83.
241. Roberson DW, Kentala E, Forbes P. Development and validation of an objective instrument to measure surgical performance at tonsillectomy. Laryngoscope. 2005 Dec;115(12):2127-37.
242. Mekasha A. Assessment methods in medical education. Ethiop Med J. 2004 Jan;42(1):63-71.
243. Datta V, Mandalia M, Mackay S, Chang A, Cheshire N, Darzi A. Relationship between skill and outcome in the laboratory-based model. Surgery. 2002 Mar;131(3):318-23.
244. Minnich DJ, Schell SR. Evaluation of face-mounted binocular video display for laparoscopy: outcomes of psychometric skills testing and surgeon satisfaction. J Laparoendosc Adv Surg Tech A. 2003 Oct;13(5):333-8.
245. Bann S, Datta V, Khan M, Darzi A. The surgical error examination is a novel method for objective technical knowledge assessment. Am J Surg. 2003 Jun;185(6):507-11.
246. Larson JL, Williams RG, Ketchum J, Boehler ML, Dunnington GL. Feasibility, reliability and validity of an operative performance rating system for evaluating surgery residents. Surgery. 2005;138(4):640-7.
247. Lockyer J. VC. An Examination of the Appropriateness of using a common peer assessment instrument to assess physician skills across specialties. Academic Medicine. 2004;79(10).
248. Shime J, Pittini R, Szalai JP. Reliability Study of the Laparoscopic Skills Index (LSI): a new measure of gynecologic laparoscopic surgical skills. J Obstet Gynaecol Can. 2003 Mar;25(3):186-94.
249. Macluskey M, Hanson C, Kershaw A, Wight AJ, Ogden GR. Development of a structured clinical operative test (SCOT) in the assessment of practical ability in the oral surgery undergraduate curriculum. Br Dent J. 2004 Feb 28;196(4):225-8.
250. Harden RM. Trends and the future of postgraduate medical education. Emerg Med J. 2006 Oct;23(10):798-802.
251. Hauer KE, Hodgson CS, Kerr KM, Teherani A, Irby DM. A National Study of Medical Student Clinical Skills Assessment. Academic Medicine 2005;80(10):s25-s9.
252. Cooke.M ID, Sullivan. W., Lundmer. K. American Medical Education 100 years after the Flexner Report. New England Journal of Medicine. 2006;355(13):1339-134.
253. Regehr G. Trends in medical education research. Academic Medicine. 2004;79 (10), 939-947.(79 (10)):939-47.
254. Klein B. Contemporary Learning Theories. Hillsdale, NJ: Lawrence Erlbaum Associates; 1989.

255. Bower G. Theories of learning. Englewood; NJ: Prentice-Hall; 1981.
256. Hergenhahn. B. An introduction to Theories of Learning. New Jersey: Prentice-Hall; 2005.
257. Lefrancois G. Thoeries of Human Learning. Pacific Grove, CA, U.S.A.: Brooks/Cole Publishing; 1995.
258. Amin Z. Theory and practice in continuing medical education. Ann Acad Med Singapore. 2000 Jul;29(4):498-502.
259. Terrell M. Anatomy of learning: instructional design principles for the anatomical sciences. Anat Rec B New Anat. 2006 Nov;289(6):252-60.
260. Malcolm C, Irby, D., Reznick, R., MacRae, H. Teaching Surgical Skills — Changes in the Wind. New England Journal of Medicine. 2006;355:2664-9.
261. Furedy JJ. Arguments for and proposed tests of a revised S-R contiguity-reinforcement theory of human Pavlovian autonomic conditioning: some contra-cognitive claims. Biol Psychol. 1988 Oct;27(2):137-51.
262. Brainerd CJ. Piaget's Theory of Intelligence. NJ: Prentice-Hall.; 1978.
263. Piaget J. The psychology of intelligence. New York: Harcourt, Brace & World; 1950.
264. Gagne R, Driscoll, M. The Conditions of Learning (4th ed.)
New York Holt, Rinehart & Winston 1985.
265. Bandura A. Social Cognitive Theory. London, England: Jessica Kingsley Publishers; 1992.
266. Bandura A. Social cognitive theory: An agentic perspective. Annual Review of Psychology Vol 52 2001, 1-26. 2001.
267. Bandura A. Social Learning Theory. New Jersey: Prentice-Hall; 1976.
268. Gagne RD, M. . Essentials of Learning for Instruction (2nd Ed.) Englewood Cliffs, NJ: Prentice-Hall. ; 1988.
269. Miller GA, Galanter, E., & Pribram, K.H. . Plans and the Structure of Behavior. New York: Holt, Rinehart & Winston; 1960.
270. Miller GA. The magical number seven, plus or minus two: Some limits on our capacity for processing information. . Psychological Review,. 1976; 63 81-97.
271. Meiser T, Hewstone M. Cognitive processes in stereotype formation: the role of correct contingency learning for biased group judgments. J Pers Soc Psychol. 2004 Nov;87(5):599-614.
272. Levett-Jones TL. Self-directed learning: implications and limitations for undergraduate nursing education. Nurse Educ Today. 2005 Jul;25(5):363-8.
273. Cross KP. Adults as Learners. San Francisco Jossey-Bass. ; 1981.
274. Sweller J. Cognitive load during problem solving: Effects on learning. Cognitive Science. 1998;12 (1):257-85.
275. Sweller J. Instructional Design in Technical Areas. Camberwell, Victoria, Australia: Australian Council for Educational Research 1999.

276. Moulton CA, Dubrowski A, Macrae H, Graham B, Grober E, Reznick R. Teaching surgical skills: what kind of practice makes perfect?: a randomized, controlled trial. Ann Surg. 2006 Sep;244(3):400-9.
277. Spiro RJ, Feltovich, P.J., Jacobson, M.J., & Coulson, R.L. Constructivism and the Technology of Instruction. Hillsdale, NJ: Erlbaum.; 1992.
278. Spiro. DNR. Cognition, Education, and Multimedia. . Hillsdale, NJ Erlbaum. ; 1990.
279. Lave J, & Wenger, E. . Situated Learning: Legitimate Peripheral Participation. . Cambridge, UK: Cambridge University Press.; 1990.
280. McLellan H. Situated Learning Perspectives. . Englewood Cliffs, NJ: Educational Technology Publications. ; 1995.
281. Wallin L, Ewald U, Wikblad K, Scott-Findlay S, Arnetz BB. Understanding work contextual factors: a short-cut to evidence-based practice? Worldviews Evid Based Nurs. 2006;3(4):153-64.
282. Grimshaw JM, Eccles MP. Is evidence-based implementation of evidence-based care possible? Med J Aust. 2004 Mar 15;180(6):S50-1.
283. Grol R, Wensing M. What drives change? Barriers to and incentives for achieving evidence-based practice. Med J Aust. 2004 Mar 15;180(6 Suppl):S57-60.
284. Guyatt GH. Evidenced-Based medicine. Journal of American Medical Association. 1991;114:A-16.
285. Grol R, Grimshaw J. Evidence-based implementation of evidence-based medicine. Jt Comm J Qual Improv. 1999 Oct;25(10):503-13.
286. Parkin C, Bullock I. Evidence-based health care: development and audit of a clinical standard for research and its impact on an NHS trust. J Clin Nurs. 2005 Apr;14(4):418-25.
287. Group E-W. Evidence Based Medicine: a new approch to the teaching of medicine. Journal of American Medical Association. 1992;268:2420-5.
288. Tosteson DC. Learning in medicine. New England Journal of Medicine 1979;301(13):690-4.
289. Letterie GS. Medical education as a science: the quality of evidence for computer-assisted instruction. Am J Obstet Gynecol. 2003 Mar;188(3):849-53.
290. McAllister M, Osborne SR. Teaching and learning practice development for change. J Contin Educ 2006;37(4):154-9.
291. Feletti DBG. The Challenge of Problem Based Learning. . New York: St. Martin’s Press. ; 1991.
292. Barrows HS. A Taxonomy of Problem Based Learning Methods. . Medical Education. 1986(20):481-6. .
293. Barrows HS, Tamblyn, R. Problem-Based Learning: An approch to medical education. . Medical Education. 1980;1.
294. Barrows HS. How to design a problem-based curriculum for the preclinical years. . New York: Springer Publishing Co. ; 1985.

295. Rogers DA, Regehr G, Yeh KA, Howdieshell TR. Computer-assisted learning versus a lecture and feedback seminar for teaching a basic surgical technical skill. Am J Surg. 1998 Jun;175(6):508-10.
296. Rogers DA, Elstein AS, Bordage G. Improving continuing medical education for surgical techniques: applying the lessons learned in the first decade of minimal access surgery. Ann Surg. 2001 Feb;233(2):159-66.
297. Ahlering TE, Skarecky D, Lee D, Clayman RV. Successful transfer of open surgical skills to a laparoscopic environment using a robotic interface: initial experience with laparoscopic radical prostatectomy. J Urol. 2003 Nov;170(5):1738-41.
298. Aggrawal R, Darzi, M. Technical-Skills Training in the 21st Century. New England Journal of Medicine. 2006;355(25):2695-6.
299. Hodges NJ, Franks IM. Modelling coaching practice: the role of instruction and demonstration. J Sports Sci. 2002 Oct;20(10):793-811.
300. Al-Abood SA, Davids K, Bennett SJ, Ashford D, Martinez Marin M. Effects of manipulating relative and absolute motion information during observational learning of an aiming task. J Sports Sci. 2001 Jul;19(7):507-20.
301. Badets A, Blandin Y, Wright DL, Shea CH. Error detection processes during observational learning. Res Q Exerc Sport. 2006 Jun;77(2):177-84.
302. Downing S. HT. Hand Book of Test Development. 2006.
303. Crocker LM. Introduction to classical and modern test theory. New York: Holt, Rinehert and Winston; 1986.
304. Janda LH. Psychological Testing: Theory and Applications. Boston: Allyn and Becon; 1998.
305. Hopkins K. Educational and Psychological measurement and evaluation. Allyn &Bacon; 1998.
306. Krelinger F. Foundation of Behavioral research(4thEdition). . Harcourt Brace: Toronto.; 2000.
307. Lang N. Assessment of Surgical Education. Am J of Surg. 2002;183(2):106-9.
308. Rogers DA, Regehr G, MacDonald J. A role for error training in surgical technical skill instruction and evaluation. Am J Surg. 2002 Mar;183(3):242-5.
309. Feldman LS, Hagarty SE, Ghitulescu G, Stanbridge D, Fried GM. Relationship between objective assessment of technical skills and subjective in-training evaluations in surgical residents. J Am Coll Surg. 2004 Jan;198(1):105-10.
310. Malcolm C, Irby, D., Reznick, R., MacRae, H. Teaching Surgical Skills — Changes in the Wind. New England Journal of Medicine; Medical Education. 2006;.(355):2664-9.
311. Margery D. KI. The place of the oral examination in today's assessment systems. Medical Teacher. 2005;27(4):294-7.

312. Mekasha. Assessment methods in medical education
Ethiop Med J 2004 2004;42(Jan;42(1)):63-71.
313. Rafiq A, Broderick TJ, Williams DR, Doarn CR, Jones JA, Merrell RC. Assessment of simulated surgical skills in parabolic microgravity. Aviat Space Environ Med. 2005 Apr;76(4):385-91.
314. Friedlich M. Is it feasible to include a technical station on a national licensing examination? Am J of Surg. 2007;193(1):86-9.
315. Cremers SL, Ciolino JB, Ferrufino-Ponce ZK, Henderson BA. Objective Assessment of Skills in Intraocular Surgery (OASIS). Ophthalmology. 2005 Jul;112(7):1236-41.
316. Hislop SJ, Hsu JH, Narins CR, Gillespie BT, Jain RA, Schippert DW, et al. Simulator assessment of innate endovascular aptitude versus empirically correct performance. J Vasc Surg. 2006 Jan;43(1):47-55.
317. Hambleton R. Item Response Theory. Kluwer-Nijhoff; 1985.
318. Thorndike RL. Educational Measurement Washington, D. C: American Council on Education.; 1971.
319. Wainer H BI. Validity: An evolving concept. Hillsdale, NJ: Lawrence Erlbaum; 1988.
320. Karnath BM, Thornton WM, Frye AWP. Teaching and Testing Physical Examination Skills without the Use of Patients. . Academic Medicine. 2002;77(7):753.
321. Fischer G H. Applying the principles of specific objectivity and Generalizability to the measurement of change. . Psychometrika. 1987;52(4):565-87.
322. Cronbach L J, Nageswari, R., & Gleser, G.C. . Theory of Generalizability: A liberation of reliability theory. The British Journal of Statistical Psychology. 1963;16 137-63.
323. Cronbach. L GG, Nanda H, Rajaratnam. The dependability of behavioral measurement: Theory and Generalizability for source and profiles. New York: Jhon Wiley & Sons; 1972.
324. Lien A. Measurement and Evaluation of Learning. Iowa: Brown Company; 1976.
325. Woolson R. CW. Statistical Methods for the analysis of biomedical data. 2nd ed.: Wiley and Sons; 2002.
326. R.K. Hambleton HS. Item Response Theory: Principles and Applications. 1985.
327. Quirk M. MK, Haley HL., Wellman S. ,Keller D. ,Hatem D. ,Keller LA Reliability and validity of checklists and global ratings by standardized students, trained raters, and faculty raters in an objective structured teaching environment. Teaching & Learning in Medicine. 2005;17(3):202-9.
328. Cronbach. L. Essentials of Psychological Testing. 1070.

329. Vassiliou MC, Feldman LS, Andrew CG, Bergman S, Leffondre K, Stanbridge D, et al. A global assessment tool for evaluation of intraoperative laparoscopic skills. Am J Surg. 2005 Jul;190(1):107-13.
330. Brydges R, Classen R, Larmer J, Xeroulis G, Dubrowski A. Computer-assisted assessment of one-handed knot tying skills performed within various contexts: a construct validity study. Am J Surg. 2006 Jul;192(1):109-13.
331. Emken JL, McDougall EM, Clayman RV. Training and assessment of laparoscopic skills. Jsls. 2004 Apr-Jun;8(2):195-9.
332. Shah J, Munz Y, Manson J, Moorthy K, Darzi A. Objective assessment of small bowel anastomosis skill in trainee general surgeons and urologists. World J Surg. 2006 Feb;30(2):248-51.
333. Moon MR, Damiano RJ, Jr., Patterson GA, Gay WA, Jr., Cooper JD. Effect of a cardiac-specific didactic course on thoracic surgery in-training examination performance. Ann Thorac Surg. 2003 Apr;75(4):1128-31.
334. McDonald FSM, Ramakrishna GM, Schultz HJM. A Real-time Computer Model to Assess Resident Work-hours Scenario. Academic Medicine. 2002;77(7):752.
335. Violato C. Predicting Clinical Performance: Does the Medical College Admission Test Predict Clinical Reasoning Skills? A Longitudinal Study Employing the Medical Council of Canada Clinical reasoning Examination Academic Medicine. 2005;80(10).
336. Kushniruk AW, Patel VL. Cognitive and usability engineering methods for the evaluation of clinical information systems. Journal of Biomedical Informatics. 2004 Feb;37(1):56.
337. Nielsen. Usability engineering. . New York: Academic Press; 1993.: New York: Academic Press; 1993.; 1993.
338. Rossen MB CJ. Usability Engineering. . 2002.
339. Nagendran S. Humphries P Cabin Fever 2004: Teaching beyond the basics. Family Medicine Faculty Development Workshop Proceedings. 2004.
340. Bloom. Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain. New York: David McKay Co Inc 1956.
341. Duplaga M, Juszkiewicz K, Leszczuk M. Telelearning standards and their application in medical education. Stud Health Technol Inform. 2004;105:308-16.
342. Gandsas A, Park A, McIntire K. Live broadcast of laparoscopic surgery to handheld computers. Surgical Endoscopy. 2004;18(6):997.
343. Heller AC, Amar AP, Liu CY, Apuzzo ML. Surgery of the mind and mood: a mosaic of issues in time and evolution. Neurosurgery. 2006 Oct;59(4):720-33; discussion 33-9.

344. Tegtmeyer K, Ibsen L, Goldstein B. Computer-assisted learning in critical care: from ENIAC to HAL. [Review] [28 refs]. Critical care medicine. 2001 Aug;29(8 Suppl):N177.
345. Ahlberg G, Heikkinen T, Iselius L, Leijonmarck CE, Rutqvist J, Arvidsson D. Does training in a virtual reality simulator improve surgical performance? Surg Endosc. 2002 Jan;16(1):126-9.
346. Fitts PM PM. Human Performance. Belmont, CA: Brooks/Cole; 1967.
347. Bandura A. Social Learning Theory. Prentice-Hall Inc; 1977.
348. Kintsch W CJ. Introduction to the 100th anniversary issue of the Psychological Review. . Psychological Review. 1994;101: 195-199
349. Kirschner PS, J. Clark, R. . Why minimal guidence during instruction does not work: An analysis of the faliure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. Educational Psychologist. 2006;41(2):75-86.
350. Sweller J. Cognitive load during problem solving: Effects on learning. Cognitive Science 1988;12, 257-285.
351. Bruner J. Studies in cognitive growth : A collaboration at the Center for Cognitive Studies. . New York: Wiley & Sons. ; 1966.
352. Bruner J. Toward a theory of instruction. . Cambridge: Harvard University Press. ; 1974.
353. Beilin H FG. The foundation of Piaget's theories: mental and physical action. Adv Child Dev Behav. 1999;27:221-46. Review.
354. Miller GA, Galanter, E., & Pribram, K.H. (1960). . Plans and the Structure of Behavior. . New York: Holt, Rinehart & Winston. ; 1960.
355. Miller GA. The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review. 1956; 63, 81-97.
356. Bull DA, Stringham JC, Karwande SV, Neumayer LA. Effect of a resident self-study and presentation program on performance on the thoracic surgery in-training examination. Am J Surg. 2001 Feb;181(2):142-4.
357. Beckmann CRB, Lipscomb GH, Ling FW, Beckmann CA, Johnson H, Barton L. Computer-assisted video evaluation of surgical skills. Obstetrics and Gynecology. 1995;85(6):1039.
358. Scerbo MW, Bliss JP, Schmidt EA, Hanner-Bailey HS, Weireter LJ. Assessing surgical skill training under hazardous conditions in a virtual environment. Stud Health Technol Inform. 2005;111:436-42.
359. Acosta E, Temkin B. Haptic laparoscopic skills trainer with practical user evaluation metrics. Stud Health Technol Inform. 2005;111:8-11.

Appendices

Appendix A: Test Instrument for Study 1

The Design of an e-Knowledge Medel (e-KM) and the study of its Efficacy

PhD – Research Study

Assessment Instrument (test) for sebaceous cyst removal

30 questions multiple choice

PLEASE CIRCLE THE CORRECT ANSWER

Q1) What is the common cause of a sebaceous cyst?

1) Swollen hair follicle
2) Sun damage
3) Gardner's syndrome
4) Steroids

Q2) Which of the following is not a sebaceous cyst?

1) A nontender, small lump beneath the skin
2) Mobile masses that consist of fibrous tissues and fluids
3) Abnormal sac or closed cavity lined with epithelium and filled with fluid or semisolid material
4) Firm solid mass under the skin

Q3) Identify the erroneous differential diagnosis for a sebaceous cyst

1) Melanoma
2) Lipoma
3) Herpes
4) Erythema marginatum

Q4) Commonly used clamp for the sebaceous cyst removal is

1) Allis clamp
2) Tonsil clamp
3) Babcock clamp
4) Right-angle clamp

Q5) COUMADIN can be best described as

1) A long-term anticoagulant
2) Inhibits B-dependent clotting factors II, VII,IX,X
3) The half-life effect is 200 hours
4) Monitored effects by partial thromboplastine time(PTT)

Q6) What are possible antiseptic agents?

1) Lidocaine
1) Betadine
2) Benzedine
3) Saline

Q7) What is the dosage of lidocaine that can be used as a local anaesthetic?

1) 1% lidocaine; 20mg/kg
2) 1% lidocaine with epinephrine; 7mg/kg
3) 1% lidocaine; 7mg/kg
5) 1% lidocaine with epinephrine; 20mg/kg

Q8) Identify the instrument used for small surgery

1) Hemostat clamp
2) Mayo scissor
3) Debakey clamp
4) Gerald forceps

Q9) Which of the following is not an alternate name for the cyst

1) Epidermal_cyst
2) Keratin cyst
3) Epidermoid cyst
4) Keratosis pillares cyst

Q10) What type of analgesic medication is appropriate for removal of a sebaceous cyst?

1) Lidocaine and Fentanyl
2) Bupivicaine and Fentanyl
3) Bupivicaine and Lidocaine
4) Fentanyl

Q11) Where is the local anaesthetic injected?
1) Dermis and Epidermis
2) Vein
3) Artery
4) Fibrous Fascia

Q12) Post operatively when do sutures come out?
1) 1-2 days
2) 3-6 days
3) 7-10 days
4) 11-20 days

Q13) Common site for a sebaceous cyst is
1) Face and neck
2) Palm, foot
3) Small bowel
4) Along the Cantle's line

Q14) What type of suture needle is used for closing skin?
1) Hollow needle
2) Cutting needle
3) Non-cutting needle
4) Forked needle

Q15) Identify the absorbable suture
1)PDS
2)Silk
3)Prolene
4)Nylon

Q16) Which one of the following is not the correct treatment for the cyst
1) Surgery
2) Ignore it
3) Injection of steroid
4) Injection of 5-fluorouracil (5-Fu)

Q17) What is the medical school philosophy for wound closure?
1)Approximate, don't strangulate
2) Make sure it is as tight as it can be
3) Overlap edges
4) Always with a graft

Q18) What is the commonly used stitch for sebaceous cyst removal?

1)Subcuticular stitch
2) Pursestring stitch
3) Figure 8 stitch
4) Retention suture

Q19) Which of the following is not a basic surgical knot?
1) Square knot
2) Instrument knot
3) Surgeon's knot
4) COAG knot

Q20) What is the plane of dissection?
1) Langer's line
2) Rocky-Davis
3) Kocher
4) Kobeler's line

Q21) A commonly used blade for this procedure is
1) No. 11 blade
2) No. 18 blade
3) No. 20 blade
4) No. 21 blade

Q22) Identify the nonabsorbable suture
1)PDS
2)Vicryl
3)Prolene
4)Cat gut

Q23) What is the most immediate and effective method to obtain hemostasis?
1) Pressure (finger)
2) Ice
3) Fibrin glue
4) Surgicel

Q24) What is the preferred method of wound healing?
1) Primary intention
2) Secondary intention

3) Tertiary intention
4) Primary closure, Tertiary intention

Q25) What are the symptoms of infection?
1)Redness and tenderness of the site
2) Foul-smelling material may drain from the cyst
3) Increase warmth of skin over site
4) Distend stomach

Q26) At time of surgery which one of the following is not considered a complication?
1) A cyst disguised as a tumor
2) The sac is larger than anticipated
3) Blood clot
4) Anterio venous fistula

Q27) What common medication irreversibly inhibits platelets by irreversibly inhibiting cyclo-oxygenase?
1) Aspirin
2) Tylenol
3) Ibuprofen
4) Indomethacin

Q28) Post operative wound infection is least likely to be caused by
1) Staphylococus aureus
2) Staphylococus epidermidis
3) Group A Staphylococus
4) E.Coli

Q29) How does the patient keep the wound clean?
1) soak in bath tub over 30 minutes per day
2) scrub wound in shower
3) do not wet wound
4) allow water to run off wound and pat dry

Q30) What post operative information need not be given to patient prior to discharge?
1) wound care
2) signs of infection
3) rate of cyst reoccurrence

4) need for eventual skin graft

Appendix B: Test Instrument for Study 2

The Design of an e-Knowledge Medel (e-KM) and the study of its Efficacy
PhD – Research Study
Assessment Instrument (test) for sebaceous cyst removal
35 questions multiple choice

<u>PLEASE CIRCLE THE CORRECT ANSWER</u>

Q1) What is the common cause of a sebaceous cyst?
1) Swollen hair follicle
2) Sun damage
3) Gardner's syndrome
4) Steroids

Q2) Which of the following is not a sebaceous cyst?
1) A nontender, small lump beneath the skin
2) Mobile masses that consist of fibrous tissues and fluids
3) Abnormal sac or closed cavity lined with epithelium and filled with fluid or semisolid material
4) Firm solid mass under the skin

Q3) Identify the erroneous differential diagnosis for a sebaceous cyst
1) Melanoma
2) Lipoma
3) Herpes
4) Erythema marginatum

Q4) Commonly used clamp for the sebaceous cyst removal is
5) Allis clamp
6) Tonsil clamp
7) Babcock clamp
8) Right-angle clamp

Q5) COUMADIN can be best described as

1) Anticoagulant
2) Inhibits B-dependent clotting factors III, VI
3) The half-life effect is 200 hours
4) Monitored effects by partial thromboplastine time(PTT)

Q6) What are possible antiseptic agents?

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6) Saline

Q7) What is the dosage of lidocaine that can be used as a local anaesthetic?

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2)Silk
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4)Nylon

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1) Surgery
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3) Injection of steroid
4) Injection of 5-fluorouracil (5-Fu)

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1)Approximate, don't strangulate
2) Make sure it is as tight as it can be
3) Overlap edges
4) Always with a graft

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1)Interrupted stitch
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3) Figure 8 stitch
4) Retention suture

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1) Staphylococus aureus
2) Staphylococus epidermidis
3) Group A Streptococus
4) Clostridium botulinum

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Q30) What post operative information need not be given to patient prior to discharge?
1) wound care
2) signs of infection
3) rate of cyst reoccurrence
4) need for eventual skin graft

Q31) Informed consent is where
1) consent is implied
2) benefits and risks are understood by patient
3) benefits and risks are told to patients
4) the patient consented to come to the appointment

Q32) The sharps (scalps and needles) should be disposed
1) in a non-penetrable container
2) in the garbage bin
3) down the toilet

4) left on tray to be removed by nurse

Q33) During the procedure the physician
1) should be silent
2) may chit-chat with patient to put them at ease
3) can discuss other colleague's humorous mishaps with nurse
4) should avoid answering any questions from the patient

Q34) Ideal behaviour for a Physician is to
1) work collegially with staff
2) be in charge and demand appropriate respect from assistants
3) reprimand staff if needed during procedure
4) smile all the time

Q35) Patient confidentiality is maintained when
1) discharge summaries are sent to pharmacies
2) patient file is shared with another physician for consult
3) patient data is used for research
4) sell patient demography to vendors

Appendix C: consent form

UNIVERSITY OF
ALBERTA

<u>CONSENT FORM</u>
<u>for Students</u>

<u>TITLE:</u> The Design of an e- Knowledge Model (e-KM) and the study of its Efficacy

<u>SPONSOR:</u> None

INVESTIGATORS: Shyamala Nagendran, Dr. Claudio Violato

BACKGROUND

<u>Objective:</u> The study objective is to develop a Knowledge Model of surgical procedures in an electronic (e-KM) medium and investigate the efficacy of the model. Teaching clinical procedures via an electronic medium allows the 'see one' component to be achieved, thus providing a solution to accessibility and creating opportunities for learning. The challenge is to assess its impact on knowledge acquisition.

<u>Method</u>: The Web application will be designed utilizing Usability Engineering attribute. The research design is an experimental study design; undergraduate medical students will be randomly assigned into 2 groups. Group 1 will receive

the e-KM instruction and group 2 will receive instruction from a human teacher. Standardized surgical procedure of removing a cyst will be demonstrated for both groups and knowledge acquisition will be measured with the (multiple choice) assessment tool.

WHAT IS THE PURPOSE OF THE STUDY?

The purpose is to develop and determine the efficacy of an electronic Knowledge Model (e-KM) of a surgical procedure (cyst removal) in an electronic medium and assessing its impact on knowledge.

WHAT WOULD I HAVE TO DO?

Undergraduate medical students will be randomly assigned into 2 groups.

- Group 1 will be asked to use a computer application on the Web that demonstrates the surgical procedure of the removal a sebaceous cyst. Following which they would participate in a multiple choice assessment tool.
- Group 2 will receive instruction from a human teacher on the surgical procedure of removing a sebaceous cyst. Following which they would participate in a multiple choice assessment tool.

WHAT ARE THE RISKS?

None

ARE THERE ANY REPRODUCTIVE RISKS?

None

WILL I BENEFIT IF I TAKE PART?

Will learn about the surgical procedure of removing a sebaceous cyst.

DO I HAVE TO PARTICIPATE?

Participation is anonymous and voluntary

WHAT ELSE DOES MY PARTICIPATION INVOLVE?

Nothing else

WILL I BE PAID FOR PARTICIPATING, OR DO I HAVE TO PAY FOR ANYTHING?

No

WILL MY RECORDS BE KEPT PRIVATE?

It is anonymous volunteer participation, and no form of identification is required.

IF I SUFFER A RESEARCH-RELATED INJURY, WILL I BE COMPENSATED?

Participation in the Study 1s not expected to be harmful.

In the event that you suffer injury as a result of participating in this research, no compensation will be provided to you by the University of Calgary, the Calgary Health Region or the Researchers. You still have all your legal rights. Nothing said in this consent form alters your right to seek damages.

CONSENT

Your willingness to participate in the above study would be accepted as consent. Your presence indicates that you have understood to your satisfaction the information regarding your participation in the research project and agree to participate as a subject. If you have further questions concerning matters related to this research, please contact:

Shyamala Nagendran at (780) 407-2018

If you have any questions concerning your rights as a possible participant in this research, please contact EHRB in the faculty of Medicine at the University of Alberta.