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A comparison of surgical procedure cognitive skills acquisition between the traditional apprenticeship and a digital teaching approach

By

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SUMMARY

A COMPARISON OF SURGICAL PROCEDURE COGNITIVE SKILLS ACQUISITION BETWEEN THE TRADITIONAL APPRENTICESHIP AND A DIGITAL TEACHING APPROACH

by

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Introduction: Mastering the skills required to perform a surgical procedure requires technical and cognitive skills training. However, the traditional method for teaching surgical procedures emphasises technical over cognitive skills acquisition. There is no systematic and sequential approach to teaching surgical procedure cognitive skills. This study aims to design an alternative digital teaching approach for surgical procedure cognitive skills using 3D animated videos and compare it to the traditional teaching method.

Methods: A quantitative experimental study consisting of two phases was conducted. Participants were novice medical officers and general surgery residents at the Universities of Botswana, Pretoria, and their affiliated hospitals. We used purposive sampling, and a sample size of 24 was determined. The digital teaching approach was designed using the ADDIE model during Phase I and compared to the traditional model during Phase II. The ADDIE model is an instructional design model comprising five stages: Analysis, Design, Development, Implementation and Evaluation. An instructional design model aims to help educators optimally design and teach the appropriate material. A crossover-repeated-measures study design was used to determine the difference in knowledge gain and retention using pre-, post- and retention tests. Participant satisfaction level and surgical procedure clarity were also compared.

Results: The digital teaching method of surgical procedure cognitive skills was designed using the ADDIE model of instructional design. The complete study project, including its evaluation phase, was created and administered via a learning management system (LMS). Twenty-nine (29) participants completed the study. Their mean age was 31.5 years ($SD = 3.74$). Ten were general surgery residents, and 19 were medical officers in the departments of surgery. All participants were computer literate according to the computer proficiency questionnaire conducted. In the learner needs assessment, all participants agreed that surgical procedure cognitive skills needed to be taught systematically and sequentially. The paired sample t-test showed the mean differenced score for the digital teaching method ($M = 3.59$, $SD = 1.48$) to be significantly greater than that of the traditional teaching method ($M = 1.93$, $SD = 1.28$), $t(28) = -10.950$, $p < 0.001$ (two-tailed). Likewise, the mean differenced retention score for the digital teaching method ($M = 2.96$, $SD = 1.480$) was significantly higher than that of the traditional teaching method ($M = 1.48$, $SD = 1.087$). Seventy-two percent (18/25) preferred the digital teaching method over the traditional one. In a 12-item questionnaire, all rated the digital teaching method more highly than the traditional one in teaching surgical procedure cognitive skills.

Conclusion: Students who were taught surgical procedure cognitive skills using the digital teaching method had greater knowledge gain and retention when compared to those taught using the traditional teaching method. Additionally, participants were more satisfied with the digital than with the traditional approach to teaching surgical procedure cognitive skills. They considered the digital teaching method clearer than the traditional one. The researcher recommends adopting the digital teaching method for teaching surgical procedure cognitive skills to produce surgeons competent in decision-making. The assumption is that this would lead to improved surgical outcomes.

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Keywords: 3D animation, Apprenticeship training, Cognitive skills, Digital teaching method, Digital training, Halstedian model, Surgical cognitive skills, Surgical skills, Surgical training, Traditional surgical training.

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Research Outputs

Conference presentations

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1. Mpapho Joseph Motsumi, Martin Brand, Irene Lubbe, Lucky Mokgatlhe. A comparison of surgical procedure cognitive skills acquisition between the traditional apprenticeship model and 3D animation with programmatic assessment. 49th Surgical Research Society Hybrid Meeting; Sefako Makgatho Sciences University, GE Conference Centre, Melrose Estate, Johannesburg. 8th -9th July 2022. Appendix 2.1 - Acceptance letter for oral presentation.
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2. Mpapho Joseph Motsumi, Martin Brand, Irene Lubbe, Lucky Mokgatlhe. Phase II: A comparison of surgical procedure cognitive skills acquisition between the traditional apprenticeship and a digital teaching approach. Submitted to Journal of Medical Education and Curricular Development 20/07/2023, Manuscript ID MDE-23-0158. Appendix 2.4 – Manuscript submission letter.

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List of abbreviations

3D	3-Dimensional
ADDIE	Analysis, Design, Development, Implementation and Evaluation
ANC	Axillary Node Clearance
AT	Assessment Tasks
BKA	Below Knee Amputation
CDM	Clinical Decision-Making
CTA	Cognitive Task Analysis
EMQ	Extended Matching Question
FHS	Faculty of Health Sciences
IHR	Inguinal Hernia Repair
ILOs	Intended Learning Outcomes
LA	Learning Analytics
LMS	Learning Management System
MCQ	Multiple Choice Question
NRH	Nyangabgwe Referral Hospital
OA	Open Appendicectomy
PMH	Princess Marina Hospital
RACS	Royal Australasian College of Surgeons
REC	Research Ethics Committee
SBAH	Steve Biko Academic Hospital
SLH	Scottish Livingstone Hospital
SME	Subject Matter Expert
SOLO	Structure of Observed Learning Outcomes
TKA	Total Knee Arthroplasty
TLAs	Teaching Learning Activities
UB	University of Botswana
UP	University of Pretoria
URL	Uniform Resource Locator

Declaration

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I declare that the dissertation/thesis, which I hereby submit for the degree PhD in Surgery at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Ethics Statement

The author, whose name appears on the title page of this dissertation/thesis, has obtained, for the research described in this work, the applicable research ethics approval.

The author declares that he has observed the ethical standards required in terms of the University of Pretoria's Code of Ethics for Researchers and the Policy guidelines for responsible research.

Mpapho Motsumi

August 2023

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Chapter 1. Introduction

The apprenticeship model of surgical training is the gold standard worldwide and has a longstanding, rich history. However, increasing evidence shows that this traditional method of teaching surgical procedures covers cognitive skills inadequately. Therefore, the traditional teaching method for surgical procedures may produce surgeons who are not fully proficient in cognitive decision-making, which might negatively influence patient outcomes. This study designed a digital teaching method for surgical procedure cognitive skills and compared it to the traditional teaching method. The background of the study is presented in the next section.

1.1 Background

The history of the apprenticeship model is presented first to provide a glimpse into its current state, with a special focus on Europe, America and Africa. The discussion will then develop further, focusing on the traditional method of teaching surgical procedures and its inadequacy in teaching surgical procedure cognitive skills. Context is further added to the discussion by considering Bloom's taxonomy of the cognitive learning domain. Next, the reasons for the inadequacy of the traditional teaching method are further reviewed in the literature. This will be followed by reviewing the suggested methods and tools for teaching surgical procedure cognitive skills. The chapter will conclude by presenting the aim of the study, the rationale, the hypothesis, and the study objectives.

1.1.1 The history of surgical training

The first official record of an organised body of surgical professionals in the history of English surgery comes from the Company of Barber-Surgeons of London, established in 1540. This body was responsible for teaching and training apprentices, practice licensing, and appointing surgeons to the army. Apprentices were trained by observing their teachers over the years[1]. The Company of Barber-Surgeons of London eventually evolved to form the Company of Surgeons in 1745 and, ultimately, the Royal College of Surgeons in 1800, which now provides education, assessment and development of surgical professionals[2].
Until 1889, there was no organised surgical training programme in America, and apprenticeships served the purpose of training[3]. William Stewart Halsted (1852-1922) is credited for introducing a formal training programme for young surgeons in America. This was at the Johns Hopkins Hospital. William Halsted was influenced by the Germanic system he observed during his two years of training abroad from 1878 to 1880[3, 4]. The teachings of Volkmann, Billroth, Thiersch, Bergmann and Mickulicz particularly influenced him. He noted and imported two principles of the Germanic system to America. These were the close blending of the basic sciences and patient care and the rigorous prolonged training of residents in which only the best were retained. The Halstedian surgical training model is a steeply pyramidal programme involving vigorous advancement competition [4, 5]. The average term of service to proceed to the chief residency position in the hospital was about eight years. This included six years as an assistant and two years as a house surgeon[3]. William Halsted's main modification of the Germanic system was concentrating the responsibility and authority on the resident rather than the chief resident, who had

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completed eight years of training. However, the Halstedian model was still based on hospital-based apprenticeship training[6].

The Colleges of Surgery in Africa also follow the hospital-based apprenticeship model of surgical training[7, 8]. However, no documentation of formal surgical training in Africa existed before the mid-1900s. The College of Physicians and Surgeons of South Africa (CPSSA) was founded in 1954 and registered as a non-profit company in 1955[9, 10]. In October 1971, the all-inclusive College of Medicine of South Africa was established, which later changed to the Colleges of Medicine of South Africa (CMSA) in April 1998, following the conversion of faculties to colleges. The College of Surgeons of South Africa (CSSA) is a constituent college of CMSA. It is tasked with sustaining and improving postgraduate medical education and training in Southern Africa as an independent examining body[10].

The Association of Surgeons of East Africa (ASEA) was formally inaugurated in Nairobi on the 9th of November, 1950. In November 1996, at the 25th Regional Health Ministers Conference in Mauritius, the first concrete steps towards forming a College of Surgeons were taken [11]. Subsequently, the College of Surgeons was inaugurated at the annual general meeting (AGM) of ASEA held in Nairobi on 1st December 1999. A resolution was made to register the College in constituent countries of ASEA and identify training hospitals and trainees. The college was initially named the College of Surgeons of East and Central Africa (COSECA). The name was later changed to the College of Surgeons of East, Central and Southern Africa (COSECSA) at the first COSECSA AGM held in Lusaka on the 5th of December 2001.

The Association of Surgeons of West Africa (ASWA) was formed in 1960 and later transformed into the West African College of Surgeons (WACS) in 1973[12]. It was first established to foster fellowship amongst the first surgeons of West African origin returning from overseas training[13]. WACS became an autonomous training body in 2000 with seven Faculties (Surgery, Dentistry, Obstetrics & Gynaecology, Ophthalmology, Otorhinolaryngology, Radiology and Anaesthesiology).

1.1.2 **The inadequacy of traditional teaching method**

The apprenticeship model of surgical training is practiced worldwide. It has its basis in a strong relationship between the trainer and trainee formed over many years of working together closely[14]. In this training model, the method of teaching a surgical procedure entails a surgical trainee incrementally developing the skills required to perform an entire surgical procedure by repeatedly observing the trainer. The process is traditionally carried out on live patients in the operating room[15]. A surgical procedure involves an incision with instruments to repair damage or arrest disease in a living body[16]. This method of teaching a surgical procedure is summed up by the adage ‘see one, do one, teach one’[1, 17, 18]. The trainee is expected to be capable of performing a particular surgical procedure after observing the trainer perform it, followed by being able to teach another trainee [17, 18]. This method of teaching a surgical procedure in the apprenticeship model is referred to as the traditional teaching method in this study. Unfortunately, studies have shown that 28–42% of trainees feel inadequately trained to perform surgical procedures safely after this

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teaching method[17, 19, 20]. This is attributed to the emerging evidence showing that the traditional teaching method inadequately covers surgical procedure cognitive skills [8, 21-23].

Surgical procedure training requires that one master the psychomotor and cognitive skills of a surgical procedure [24, 25]. The traditional teaching method emphasises psychomotor over cognitive skills[24, 26]. Psychomotor skills encompass motor activities and are primarily movement-oriented [24, 27, 28]. Cognitive skills of a surgical procedure include higher-order thinking skills involving decision-making, error detection, problem-solving, crisis management and planning for a surgical procedure[29]. Cognitive skills of a surgical procedure enable a surgical trainee to make safe critical decisions before, during, and after the procedure[30]. Bloom's taxonomy provides educators with systematic scaffolded classifications of cognitive learning processes. A brief review of the cognitive learning domain and cognitive skills is given to situate the research problem.

The cognitive learning domain concerns acquiring, retaining and using knowledge to create new knowledge [31]. It is commonly referred to as Bloom's Taxonomy after Benjamin Bloom, who formulated the concept in 1956 with other researchers [26]. It was later apportioned into six levels of increasing complexity. These six categories of cognitive skills range from foundational lower-order cognitive skills requiring less cognitive processing to higher-order cognitive skills requiring deeper, more complex learning and greater cognitive processing[32]. The six categories were knowledge, comprehension, application, analysis, synthesis, and evaluation. Bloom's Taxonomy was subsequently revised and refined by Anderson and Krathwohl [33]. Figure 1.1 provides a summary of the revised version of Bloom's Taxonomy.

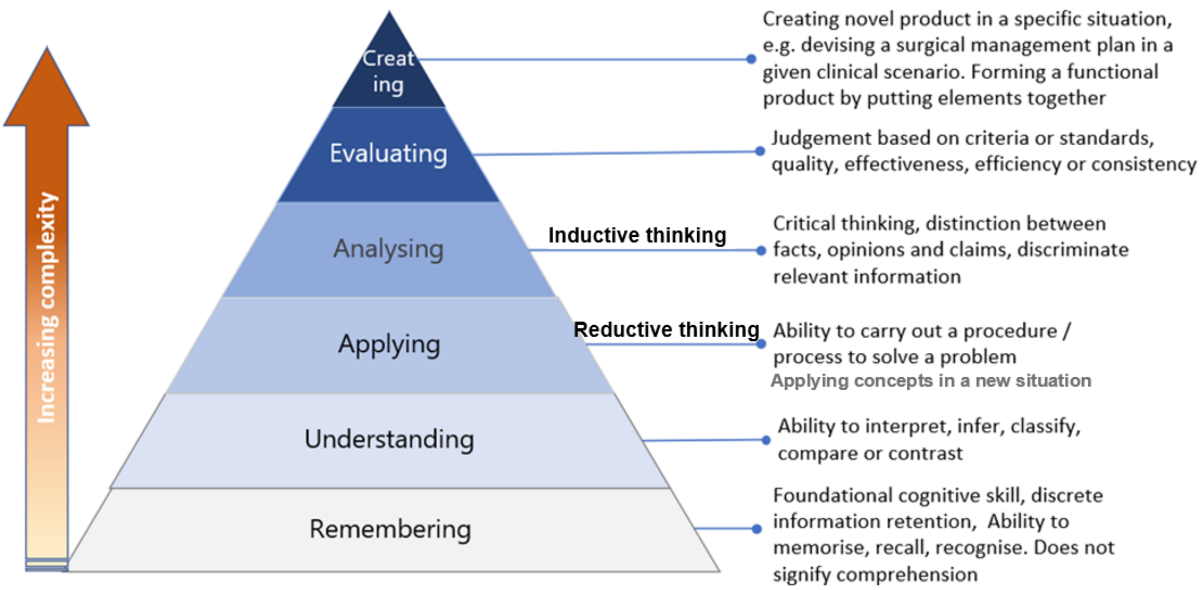

Figure 1.1 Bloom's Taxonomy.
Adapted from: Forehand M. Bloom's taxonomy. Emerging perspectives on learning, teaching, technology. 2010;41(4):47-56.

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Bloom's taxonomy is a cumulative hierarchical framework that requires the achievement of the prior skill before the next, more complex one [34]. This should be born in mind by educators as they wish to develop learners' cognitive skills to function at the higher levels described by Bloom's Taxonomy[32, 34-37]. Complex tasks such as making a critical decision during a surgical procedure require one to have the ability to function at higher thinking levels, incorporating various data points and, at times, weighing and evaluating contradicting evidence [32]. There are numerous learning taxonomies (such as Miller, SOLO, and Dreyfus) [38-40]. However, this study focuses on Bloom's Taxonomy because it relies upon the gradual increase in cognitive abilities and how they scaffold. These abilities should be sequentially developed.

Over the past three decades, the adequacy of the traditional teaching method in teaching surgical procedure cognitive skills has been increasingly critiqued[23]. Good clinical judgement through critical thinking requires grounded cognitive skills.

Kohls-Gatzoulis asserts that surgeons need to be trained to judge the appropriateness of their actions and that cognitive skills training enhances the ability to execute a surgical skill correctly[26]. In his study, junior residents were randomised to two total knee arthroplasty (TKA) training course groups. One group was taught only technical skills and had more task repetitions (5 to 6), while the other focused on teaching cognitive skills and had fewer (3 to 4) task repetitions. An objective structured assessment of technical skills (OSATS) was done for both groups pre- and post-course. Both groups completed a pre- and post-course error-detection assessment to assess cognitive skills. The performance of both groups was equivalent for the OSATS technical skills assessment, but the cognitive group scored better in the error detection assessments: $t = 2.67$, $p = 0.02$. A take-home message from this study is that good technical skills due to operative caseload do not necessarily translate into good cognitive skills. Furthermore, cognitive skills training needs to be intentional and not assumed. Next, a review of the concerns related to the traditional teaching method in teaching surgical procedure cognitive skills is provided.

One of the concerns regarding teaching surgical procedure cognitive skills in the traditional teaching method is how the training is conducted. Junior surgical trainees learn surgical procedures through observation in the operating room[24, 27, 28]. An attempt to teach cognitive skills of a surgical procedure in the operating room has direct implications for the patients: Firstly, it prolongs the operation time and thus raises ethical and legal concerns regarding patient safety [41]. Therefore, this limits the time available to teach cognitive skills during a surgical procedure. Even when educational opportunities present themselves in a clinical setting, they cannot be utilised because of the pressure for speed and maximum efficiency. This is compounded by overcrowded faculty and staff schedules[42], theatre waiting-lists and administrator expectations regarding turn-around time.

Additionally, the traditional teaching method of surgical procedures in the apprenticeship model is unpredictable since it is based on available opportunities rather than structured pre-planned educational objectives[22, 23, 42]. The knowledge acquisition for surgical trainees mainly depends on the available medical problems of

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the patients they care for[42]. There are very few standardised and systematic instructional strategies to ensure that trainees are exposed to all surgical procedure cognitive skills during training[21, 23]. Consequently, there is a lot of variation and omission of relevant information during the trainees' instruction[42].

Research also indicates that expert surgeons typically omit up to seventy percent of the information about critical actions and decisions they make when training novices. As a result, they do not report how they solve problems or perform tasks during a surgical procedure[22, 23]. The omission is attributed to this part of their embedded knowledge being procedural (the how-to knowledge), which they have mastered and which comes automatically without conscious effort. Most procedural knowledge is implicit and cannot consciously be recalled or explained. It becomes a stable component of a task over time and no longer requires conscious thought. Noel Burch called this type of procedural knowledge unconscious competence in his four stages of learning any new skill[43]. Unfortunately, trainees must be taught this part of knowledge to understand why expert surgeons do things the way they do and to build their cognitive skills in the observed procedure.

Sullivan et al. elaborated on why the traditional teaching method in the apprenticeship model is inefficient in teaching surgical procedure cognitive skills[22]. He demonstrated the unintentional omission of relevant procedural knowledge due to unconscious competence. He used cognitive task analysis (CTA) to capture steps and decision points that were not articulated during the traditional teaching of a colonoscopy. CTA gives access to the cognitive decisions that are made during procedural tasks and allows them to be broken down into discrete steps of a procedure that learners can understand. This is done through a series of structured interviews with a subject matter expert (SME). He video-recorded three expert colorectal surgeons during their traditional teaching of colonoscopy. The videotapes were later transcribed, and the experts participated in a CTA. A 26-step procedural checklist and a 16-step cognitive demands table were generated from information obtained in the CTA. The videotape transcriptions were transposed onto the procedural checklist and cognitive demands table to identify steps and decision points that were omitted during the traditional teaching. Surgeon A described 50% of "how-to" steps and 43% of decision points, Surgeon B described 30% of steps and 25% of decisions, and Surgeon C showed 26% of steps and 38% of cognitive decisions. This study demonstrates the inconsistency in knowledge transfer.

Tirapelle et al. further elaborated on the omission of relevant information due to unconscious competence[23]. He also used CTA to elicit knowledge from experts essential for comprehending a surgical procedure. The elicited knowledge was then used as instructional support for novice trainees. This elicited information would otherwise be omitted and not be transferred to the trainee during the traditional teaching method [23]. The elicited information covered major steps, tasks and decisions employed to perform the surgical procedure effectively. He argues that this information enables novices to successfully process and organise a surgical procedure's actions and decision steps. Due to their extensive experience, expert surgeons perform tasks automatically without the need for conscious guidance or monitoring. Therefore there is no guarantee that a surgical trainer will teach a trainee

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all cognitive skills of a surgical procedure because of the automaticity inherent in unconscious competence [22, 23].

Arthur Whimbey concludes that many university students have weak thinking patterns because of a lack of systematic and sequential thought. Systematic and sequential thought, which is the ability to proceed through a sequence of analytical steps, is the foundation of all higher-order reasoning and comprehension[44]. It is a cognitive skill[44]. Systematically and sequentially training cognitive skills of a surgical procedure enables the trainee to climb the cognitive function ladder and perform at higher levels (judgement and critical decision-making). Such an approach is lacking in the traditional method of teaching surgical procedures. A proficiency-based system should be used, where advancement is allowed once competence in subordinate skills has been achieved[45]. This is the scaffolding of knowledge and skills to the point of competency. For example, the trainees should demonstrate that they understand the steps of a surgical procedure outside the operating room before observing and performing it in the operating room. Novice trainees, in particular, experience challenges associated with the traditional teaching method. Such challenges include the inability to identify the most pertinent elements requiring greater attention. Secondly, they struggle to understand what happens (the how's, why's and when's) during a surgical procedure in the operating room[46]. Systematic and sequential training in surgical procedure cognitive skills is essential [22, 23, 42].

There is evidence of the inadequacy of the traditional teaching method and emerging evidence of alternative methods for teaching surgical skills[47]. However, one may perceive the dominance of the traditional teaching method as non-action. Atesok et al. attests that surgical training will change dramatically towards objective and proficiency-based approaches in the coming years [48]. He highlights the importance of this transformation trajectory in training to result in improved patient safety and educational efficiency. In his thesis, Katz presents one explanation for the lack of change from the traditional teaching method despite the emerging evidence[49]. He argues that there is no well-grounded reason to resist changes except for the recognition that these changes will affect the long-established structure, identity and culture of surgical residency training. However, it is the view of the researcher and many other authors [8, 47-49] that the accumulation of evidence will eventually direct change in the curriculum.

1.1.3 **Teaching surgical procedure cognitive skills**

Grantcharov et al. recommended a sequential surgical procedure cognitive skills training that starts with acquiring knowledge specific to the procedure, including instrumentation, surgical anatomy, indications, complications, preoperative work-up, postoperative management, and successful completion of an assessment [29]. This would then be followed by a video demonstration of the surgical procedure and an assessment of the understanding of the steps of the surgical procedure. He recommended that these steps precede an attempt to observe or perform a surgical procedure in the operating room.

The literature also suggests that educational videos effectively teach surgical procedure cognitive skills [50, 51]. Shariff et al. assessed the effectiveness of video as

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an educational tool for cognitive skills acquisition in open and laparoscopic colorectal surgery[52]. Multiple operations were filmed, developed into procedural steps, and integrated into an interactive navigational platform using Adobe® Flash® Professional CS5 10.1. The teaching resource was availed online to general surgery trainees and compared with conventional teaching of cognitive skills. During an assessment survey, the video group improved their decision-making (67%) and factual and anatomical knowledge (88%), and 96% agreed that the video teaching tool was a useful cognitive skill teaching resource. The study concluded that video education was more effective for teaching cognitive skills in colorectal surgery.

I conducted a study in 2019 to assess whether instructor-created 3D animation videos were more effective than the conventional classroom-based teaching of basic surgical skills in undergraduate training. In this study, I used instructor-created 3D animation video illustrations hosted on a learning management system (LMS) to teach basic surgical procedures[51]. The basic surgical procedures included intercostal drain insertion, suprapubic catheter insertion, and central venous access. I assessed the difference in the understanding and satisfaction levels between students taught using 3D animation video illustrations and those taught using the traditional classroom-based teaching method. Students taught using 3D animation video illustrations had a better understanding and higher satisfaction levels than those taught using only the traditional teaching method [51]. The 3D animation group had a significantly higher improvement score than the traditional teaching group ($t(223)=6.701$; $p<0.001$) (experimental group, mean 3.11; control group, mean 1.51).

In surgical training, educational videos, such as recorded and 3D animation-generated videos, are not new. Video-based teaching methods are associated with significant knowledge retention, satisfaction levels, short training time and reduced learning duration[51,53, 54]. These are welcome benefits to a surgical trainee who has to study while keeping up with a busy clinical schedule[24] . In addition, 3D animation has been shown to facilitate the acquisition of cognitive [51] and technical skills [54]. The illustrative power of 3D animation videos has particularly been demonstrated in the illustration of surgical anatomy[41, 55, 56]. The dynamic topographic views of the surgical anatomy make the demonstration of the steps of a surgical technique realistic. Consequently, studies have suggested the use of 3D animation videos in teaching surgical procedures cognitive skills [24, 25, 57]. The effectiveness of 3D animation video illustrations in surgical education is attributed to their visual realism [53, 58].

The past two decades have seen an evolution of 3D animation applications enabling the creation of complex 3D models and animations[59]. The animation of 3D models, when done well, conveys a large amount of information in a short space of time[59, 60]. 3D animation is best for illustrations conveying an understanding of 3D spatial relationships[59]. Such is true for surgical procedure training. In his study looking at the benefits of 3D modelling and animation in medical teaching, Vernon concluded that the brain absorbs pictorial information better than text-based data[60]. Students were also shown to learn more, retain knowledge better, and show more interest in learning when educational videos were used[61]. Therefore, the literature suggests that 3D animation is vital in surgical procedure training.

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Additionally, assessments have been used in conjunction with teaching and learning activities (TLA) in cognitive skills training[23, 42, 44, 62]. In most of these, they served the purpose of assessing the efficacy of a teaching intervention. However, there is another role for using TLA and assessments together. It is their joint contribution to achieving the intended learning outcomes, a concept described by Professor John Biggs in 1999 as constructive alignment[63]. "Constructive" refers to the idea that students construct meaning from relevant TLAs, while "Alignment" refers to the situation whereby TLAs, and assessment tasks, are aligned to the intended learning outcomes (ILOs)[62]. Intended learning outcomes must be set clearly at the beginning of learning, telling students what, how, and to what extent they have to learn. In constructive alignment, assessments facilitate learning instead of assessing learning. Assessments and instant feedback help cement learning, especially when spaced and spread throughout the TLAs.

In the medical curriculum, assessments are traditionally performed at the end of a module (modular tests). After completing all the modules, the marks are summed up or averaged; failure to achieve a set pass mark implies underperformance. This is called summative assessment. Summative assessment is an assessment *of* learning as opposed to formative assessment, which is an assessment *for* learning. The marks achieved by the learner after the summative assessment give limited information about the details of the learner's strengths and weaknesses. Secondly, the limited feedback to the learner comes at the end of the module, denying them the opportunity to remedy their weaknesses [64, 65] and learn from their mistakes. Formative assessment involves continuous monitoring of a learner's progress towards achieving specific outcomes through regular feedback and updates to the teacher and the learner. This directs teaching and learning continuously. Continuous assessment, as the name suggests, is more formative. It assesses learners over a period of time, and the learner's abilities in specific areas are made cumulatively to facilitate further positive learning[66]. Current learning theories emphasise continuous assessments and constructive, ongoing feedback to facilitate learning.

To conclude, the identified problem of the traditional method of teaching surgical procedures is that It inadequately teaches cognitive skills. The inadequacy stems from limitations resulting from the apprenticeship approach to teaching surgical procedure cognitive skills. These include limited time for teaching cognitive skills in the operating room, ethical concerns, dependency on available clinical opportunities that are not guaranteed, and unconscious competence that limits cognitive skills transfer from experts to novices. Therefore, there is a need for a reproducible, systematic, and sequential approach to teaching surgical procedure cognitive skills to circumvent the mentioned limitations. Currently, there is very limited research that investigated reproducible, systematic, and sequential methods of teaching cognitive skills for surgical procedures.

This study designed a digital method for teaching surgical procedure cognitive skills and compared it with the traditional teaching method. The digital method used 3D animation videos with embedded continuous assessments with instant feedback to teach surgical procedure cognitive skills.

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1.2 Problem Statement

The traditional teaching method inadequately teaches cognitive skills of surgical procedures. Therefore, there is a need to conduct research investigating alternative methods that teach surgical procedure cognitive skills in a reproducible, systematic, and sequential way.

1.3 The rationale

The traditional teaching method may be responsible for producing surgeons who are not fully proficient in cognitive decision-making as there is no reproducible, systematic and sequential teaching of surgical procedure cognitive skills. If surgical trainees' cognitive skills are well grounded, they can make critical decisions before, during and after the surgical procedures. The assumption is that not only will such trainees have lower surgical morbidity and mortality rates and consequently improved surgical outcomes, but they will also become better teachers.

1.4 Research question

Could the digital teaching method be more effective than the traditional teaching method in teaching surgical procedures cognitive skills to surgical trainees?

I hypothesised that trainees who were taught surgical procedure cognitive skills using the digital teaching method would perform better than those taught using the traditional teaching method in terms of knowledge gain, knowledge retention and self-reported satisfaction level. Furthermore, I hypothesised that the trainees would find the digital teaching method to be clearer. The complete training package was delivered to the trainees via a learning management system (LMS).

1.5 Aims and Objectives

This study sought to design a digital teaching method for surgical procedure cognitive skills using 3D animation videos and continuous assessment. It was implemented and evaluated by comparing it with the traditional teaching method. An outline of how the objectives of the aims were achieved is provided next:

1. To design the digital teaching method for surgical procedure cognitive skills.

The ADDIE instructional design model was used to design the digital teaching method for surgical procedure cognitive skills. The first four stages of the ADDIE model were used to design the digital teaching method, and the last stage, the evaluation stage, was used to evaluate it by comparing the results or impact to the traditional teaching method.

2. To create teaching and learning content.

3D animation videos for surgical procedure cognitive skills were created using Autodesk® and Adobe® software packages. Assessments were created and embedded into the educational videos using the Camtasia® software. Quizzes were also created using the LMS quiz tool. The instant feedback logic was built into the education videos using Camtasia® software.

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3. To implement and evaluate the effectiveness of the digital teaching method in teaching surgical procedure cognitive skills

The digital teaching method was piloted at the universities of Botswana and Pretoria and their affiliated hospitals. The digital teaching method for surgical procedure cognitive skills was evaluated by comparing it with the traditional teaching method regarding trainee knowledge gain, satisfaction level and surgical procedure clarity. Surgical procedure clarity referred to the participant's perceived clarity of the teaching method in teaching surgical procedure cognitive skills. The knowledge gained was evaluated using pre-, post- and retention tests, while survey questionnaires were used to assess satisfaction level and surgical procedure clarity.

1.6 Unique contribution

Published research work regarding methods of teaching surgical procedure cognitive skills is currently very sparse. This study provided and expanded the knowledge about the effectiveness of the digital teaching approach for training cognitive skills for surgical procedures. The knowledge contributed by this research can be used toadapt and enhance training programmes. A well-grounded foundation of surgical procedure cognitive skills is essential for critical decision-making and reduction of patients' adverse events. Furthermore, this study provides guidance on designing and implementing a digital teaching method. This information is valuable to programme designers, directors and education policymakers.

1.7 Hypothesis

The hypothesis statements of this study are presented below:

The null hypothesis [H0]: Trainees taught surgical procedure cognitive skills using the digital teaching method would perform the same as those taught using the traditional teaching method in terms of knowledge gain, knowledge retention and self-reported satisfaction level. Furthermore, trainees would consider the teaching clarity of the two methods to be the same.

The alternative hypothesis [H1]: Trainees taught surgical procedure cognitive skills using the digital teaching method would perform better than those taught using the traditional teaching method in terms of knowledge gain, knowledge retention and self-reported satisfaction level. Furthermore, trainees would consider the teaching clarity of the digital teaching method to be better than that of the traditional method.

1.8 Role of the researcher

At the time of performing this study, I was a senior lecturer in general surgery at the Faculty of Medicine, University of Botswana (UB). I was actively involved in teaching surgical trainees. I was a registered PhD student at the Department of Surgery, University of Pretoria (UP). My contact with the research candidates at University of Pretoria was limited to their participation in the research. I was not involved in any teaching or supervisory role at UP. I was actively involved in the research project, including data collection and analysis. I did the preproduction, production and postproduction processing stages of the 3D animation videos.

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The next chapter details the methodology followed to achieve the outlined study objectives. The chapter will start by highlighting the research problem along with the hypothesis. This will be followed by a brief discussion of the researcher's philosophical beliefs, which informed the choice of the study methodology. A definition of terms, models and processes relevant to the study design will be presented. The presentation of the study design, study procedure, statistical analysis and ethical considerations will conclude the chapter.

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Chapter 2. Material and methods

This study sought to design a digital teaching method for surgical procedure cognitive skills using 3D animation videos and video-embedded continuous assessments. The literature suggests that the traditional teaching method inadequately teaches surgical procedure cognitive skills. Surgical procedure cognitive skills are the ability of a surgeon to make critical decisions before, during and after a surgical procedure[30]. Surgical procedure cognitive skills are a core competency essential for improving surgical morbidity and mortalities[67, 68]. The researcher tested the following hypothesis:

> Novice surgical trainees who were taught surgical procedure cognitive skills using the digital teaching method would perform better than those taught using the traditional teaching method in terms of knowledge gain, retention, and self-reported satisfaction level. Furthermore, I hypothesised that the trainees would find the digital teaching method clearer.

Next is the discussion of how the researcher's philosophical beliefs and assumptions informed the research methodology.

Research paradigm

Research paradigms guide scientific discoveries through their paradigm-specific assumptions and principles. All scientific research is carried out with underpinning fundamental philosophical assumptions that influence the methodology and evidence used to support it. The positivist paradigm asserts that real events can be empirically observed and explained logically. Positivist research methodology emphasizes experimentation in a lab-like environment as an objective way of producing evidence[69]. Positivism focuses on the objectivity of the research process[70] and mostly involves quantitative methodology[70, 71]. The researcher framed this study with positivist philosophical assumptions. The nature of the hypothesis aligns with the positivist philosophy. Consequently, this study utilised a quantitative research methodology.

The definition of the terms, models and processes used in this study methodology is presented first. Then, the study design, choice and appropriateness of the statistics used and ethical considerations are covered. Finally, an in-depth study procedure detailing the steps taken during the study execution is outlined.

2.1 Definition of terms, models and processes

The following terms, concepts, models and processes are defined, and their brief introduction is provided.

2.1.1 Cognitive skill acquisition

Cognitive skill acquisition involves the development of the ability to engage in processes of problem-solving, reasoning, taking decisions or reflecting in context in a given professional setting[72]. These higher-order thinking skills enable a surgeon to make safe critical decisions at every stage leading to, during, and after a surgical procedure, lowering the morbidity and mortality associated with a particular surgical procedure[30]. The learning of cognitive skills involves acquiring, retaining and using knowledge. It follows a cumulative hierarchical framework that requires achieving the

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prior lower-level skill before the next, more complex one. This is exemplified by the Bloom's taxonomy discussed in the introduction chapter[34].

2.1.2 Apprenticeship teaching approach

The apprenticeship style of teaching has a long tradition in surgical training. Central to this teaching approach is the strong relationship between the trainer and the trainee formed over many years of working together[14]. The trainer operated on live patients in the operating room while the trainee repeatedly observed him and incrementally developed the skills required to perform the whole surgical procedure over years[14, 15]. This required continuity has been broken by shifting working patterns[14]. In this way, the trainee mastered the skills of performing a surgical procedure. This teaching approach is summed up by the adage 'see one, do one, teach one which is popularly used to describe it[1, 17, 18]. The apprenticeship teaching approach covers psychomotor skills more than surgical procedure cognitive skills. Studies have shown that 28–42% of trainees feel inadequately trained to safely perform surgical procedures after this teaching method[17, 19, 20]. Emerging evidence attributes this to the inadequacy of the traditional teaching method in covering surgical procedure cognitive skills [8, 21-23]. There is a need for a teaching method that covers surgical procedures cognitive skills in a reproducible, systematic, and sequential way. In this study, the digital teaching approach is proposed.

2.1.3 Digital teaching approach

Advances in Information and Communication Technologies (ICT) have generated new opportunities for teaching and learning processes. This is particularly true for higher education institutions[73]. Educational videos have been suggested as an effective way of teaching cognitive skills related to surgical procedures [24, 51, 52, 74]. The use of educational videos with embedded continuous assessments available to trainees through a learning management system is this study's proposed digital teaching approach. The educational videos were produced using the 3D animation production pipeline. The advantages of this digital teaching approach include its online accessibility and multimodality[75]. It allows the trainee to learn at their own time and pace outside the operating room or workplace while keeping up with their busy clinical schedule[24]. The versatility of the digital teaching approach provides the opportunity for teaching surgical procedure cognitive skills in a reproducible, systematic, and sequential way[75].

2.1.4 The ADDIE Model

The ADDIE model is a well-established instructional design model [76-78]. It comprises five stages: Analysis, Design, Development, Implementation and Evaluation. An instructional design model aims to help educators optimally design and teach the appropriate material [79]. The ADDIE model provides curriculum developers with a generic, systematic framework that is easy to use in various settings. It is an iterative process with essential steps for developing an effective course or programme[80]. It has been found that using the ADDIE model leads to a content design that focuses on learning outcomes relevant to students and facilitates active learning [76-78]. In addition, the ADDIE model informs high-quality instructional design. The analysis

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phase ascertains the need or gap for the course and determines what the course will be about. After stakeholder analysis, The educator identifies the training needs and core competencies that must be developed. The educator compiles the Learning Outcomes to inform the resources, facilitation and assessment. In the design phase, educators create a blueprint describing how to deliver the instruction to achieve the objectives identified in the analysis phase. During the development phase, the instruction components are planned in detail towards the blueprint created during the design phase. During the implementation phase, educators deliver the instruction, with or without first implementing a pilot project. Finally, in the evaluation phase, educators obtain feedback about the programme and make the appropriate adjustments to the programme of instruction [79]. While the phases are described in sequence, this is an iterative back-and-forth process between all phases during the instructional design. Figure 2.1 is a summarised, diagrammatic explanation of the ADDIE model.

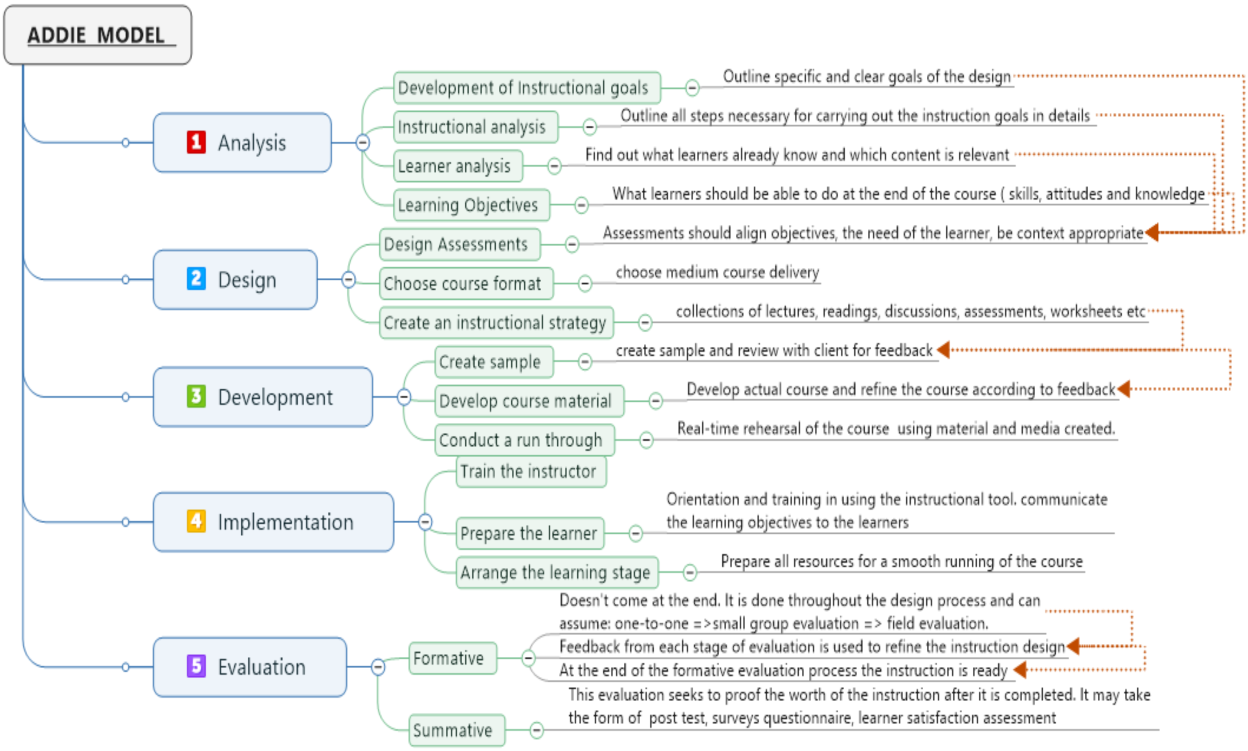

Figure 2.2 A diagrammatic representation of the ADDIE model
[created by Florida State University].

2.1.5 **Learning management system**

A learning management system is a platform that automates training events' administration, participant analytics and reporting and rapidly delivers learning content [81-83]. It has the potential for individualised learning, to provide information at the point of need, facilitate self-directed learning and promote student-centred learning[81, 83]. There are many commercial LMS options, including Moodle, Blackboard, and Brightspace, to mention a few.

Many studies have reported on the use of LMSs in medical undergraduate and postgraduate teaching [51]. Since a robust system is required for collecting and

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analysing data generated during the learner's interaction with the LMS, learning analytics (LA) will serve this purpose. Learning analytics inform the learner and the trainer, enabling them to optimise learning according to gathered feedback [65]. Lecturers use LA to identify learning difficulties, opportunities for learning support and ultimately, improvement of curriculum design, hence closing a feedback loop. It provides rich feedback information about individual students. Learning management systems provide a platform for hosting teaching and assessment activities, and communication with students can also be set to provide a continuous feedback loop.

2.1.6 **The 3D Animation video production process**

The production of 3D Animation videos follows a standard production pipeline consisting of three main stages: pre-production, production and post-production [84]. In addition, each stage consists of sub-stages which may overlap. A brief account of the many stages of 3D animation video production follows. An explainer video is also available at https://youtu.be/0ZzaDxJk5oM

Pre-Production:

a. Ideate / The Idea. An individual starts with an idea or proposed solution to a problem. Good ideas may take years to develop.
b. Script. The idea is translated into a document format known as a script by a writer. The script details the narrative through the setting, character actions, dialogue, and camera framing, creating story information. The story information is broken down into scenes and shots. A scene is made up of several shots.
c. Storyboard. The script is converted into visual representations by storyboarding it. A storyboard is like a comic book in which several sequential drawing panels map the story. Here, scene blocking and camera moves are illustrated. Storyboarding may continue throughout the production as certain story elements may change.
d. Animatic. Storyboard panels are edited together, and narration and sound effects are added to see how it flows as a video. This is known as an animatic. It acts as a blueprint for the final edit and helps determine how much animation must be produced for each shot.
e. Previsualization. Instead of developing finished elements and footage at the start, digital stand-ins help figure out camera positions, timing and movement in 3D space. Any obstacles that a shot may present can be worked out long before a lot of tedious effort has been put into the final product.
f. Design. The project signature style is developed. Guides are created to enable the digital sculpting of elements within the design parameters.
g. Modelling**.** 3D elements are modelled using a 3D software package (Autodesk® Maya 2020, 3DS Max™ and Zbrush™ 2020). There are several ways of modelling, including box modelling and sculpting from basic geometry such as spheres, cubes, cylinders and zspheres in Zbrush™ 2020. The basic geometry is transformed into a new shape in 3D modelling.
h. Rigging. After completing the modelling of characters and scene objects, the models are rigged using bones and other rigging systems to allow their manipulation. Ensuring that the 3D mesh bends and folds in the desired fashion can be very tricky and laborious. Further rigging may be required for muscles, hair, clothes and even eyes.

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i. Texturing. Digital models can be textured to almost any look, ranging from a solid colour to hand-painted or photographic imagery. This imagery is a map and can be projected onto a 3D model to simulate any imaginable surface. Texturing also controls how light behaves across that surface (like reflection and transparency). The texture map can be extracted from the model and exported as a 2D texture map that can be modified and refined on a 2D graphic design software such as Adobe® Photoshop 2020. The refined texture map is then reimported and reapplied to the model. Complex texturing can take up to three weeks.

Production:

a. Layout. Scene layouts are loosely based on their storyboard panels and closely based on their conceptual illustrations. Cameras and 3D models are set up in 3D space. Camera positions and motion are blocked out to establish a strong composition for the animators.

b. Animation. The animator uses the rigged 3D character model to create motion by manipulating it and storing sequential poses of the model over time until a complete motion is achieved on a software timeline. The points on the timeline where the poses are stored are called keys. The software can then sequentially merge the individual poses stored as keys into a realistic animation. Almost all model attributes, such as colour, form, texture, light effects, position, etc., can be animated. This gives 3D animation its dimensional look and realistic quality.
c. Lighting / Rendering. Physical lights are placed within the set and controlled for the desired final render. Rendering refers to the digital generation of the final appearance by a computer. This stage can be processor-intensive for the computer, depending on how many calculations the computer must do to produce the final 3-dimensional scene. Consequently, they are buildings filled with computers known as render farms for heavier processing. A single frame of high-definition 3D animation may take over a week to generate.

Post-Production:

Once the animation is rendered into a video, finishing touches are added to enhance the video. This can be anything from special effects to image enhancement to colour correction. In addition, music or voice overlay is done during this stage.

a. Effects. Effects such as smoke, a blade's glow, explosion, dust, flame, etc., are added to make the animation more believable.
b. Compositing. The layering of several animation shots into a complete whole is called composition. It encompasses much more, including background removal and a new background addition.
c. Editing. Editing starts at the animatic stage to ensure the shots flow at an appealing pace. Then, as production advances, the editing process continues to refine the animation.
d. Audio. Sound and music may be added earlier in the production pipeline to set the mood. However, at the end of production, the original sound may be enhanced, edited or replaced to match the final animation. In addition, the audio overlay is usually added once the final pace of the animation is set for optimal synchronisation.

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It is worth noting that though the stages of video production are given in a sequence, many may overlap or occur simultaneously. Furthermore, some sub-stages may be omitted depending on the designer's style and the project size. In addition, the production team may have a modified production pipeline depending on their resources and experience.
The defined terms, models and processes will be referenced in the next section, which presents the study design followed in this study.

2.2 Study design

This study designed a digital teaching method and compared it to the traditional teaching method. A quantitative approach was used in an experimental study design. The experimental design was chosen because it allowed the observed changes in the measured outcomes post-intervention to be attributable to the intervention. The experimental study design was appropriate because there was an intervention (training using the digital teaching method), a control group (group taught using the traditional teaching approach), and a random assignment of participants to the intervention and the control group. Random assignment to study groups is preferred to reduce confounders and increase the reliability of the results[85]. The chosen study design has been used successfully in similar studies[51, 86, 87].

The study was conducted in two phases. Phase I of the study designed the digital teaching method for surgical procedure cognitive skills using 3D animation videos and continuous assessment. During Phase II, the digital teaching method for surgical procedure cognitive skills was compared to the traditional teaching method. The compared variables were knowledge gain, retention, satisfaction level and surgical procedure clarity. Phase I and II of the study are considered separately in the subsequent chapters and sections.

The first phase (Phase I) designed the digital teaching method using the first four stages of the ADDIE instructional design model defined in the preceding section. The ADDIE model is an established iterative process with essential steps for developing an effective course or programme [76-78, 88, 89]. The second phase (Phase II) occurred during the fifth stage of the ADDIE model, the evaluation stage. The latter stage compared the traditional teaching method (Intervention 1) to the digital one (Intervention 2). Phase II, the evaluation stage, used a cross-over repeated measures study design to determine the difference in knowledge gained using pre-, post- and retention tests. In addition, the trainee satisfaction level and surgical procedure clarity were compared on a Likert scale using a survey questionnaire. Baseline information about the participants' demographics, computer proficiency, and needs assessment was also collected using survey questionnaires. Computer proficiency information was collected using an adopted and adapted computer proficiency questionnaire (CPQ-12), a validated and approved tool for training and research purposes used to assess computer proficiency[90].

The study sites were the universities of Botswana and Pretoria and their affiliated hospitals. Novice general surgery residents and medical officers who voluntarily participated in the study were included. A "novice" in this study refers to a newly qualified doctor entering a surgery department for the first time or surgical registrars in their first or second year of Registrarship.

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Purposive sampling was used. The sample size was determined to be 24 (n=24) for a 2x2 cross-over trial based on the treatment difference and the power of 80% at a 5% significance level.

The following sections cover phase I and II separately, starting with Phase I, which deals with designing the digital teaching method of surgical procedure cognitive skills using 3D animation videos and continuous assessments.

2.2.1 **Phase I: First four stages of the ADDIE model**

Phase I of the study designed the digital teaching method of surgical procedure cognitive skills using the first four stages of the ADDIE instructional design model. The first four stages of the ADDIE model include the analysis, design, development and implementation stages.

Phase I of the study addressed the first two objectives, which sought to design a digital teaching method for surgical procedure cognitive skills using 3D animation videos and embedded continuous assessments with instant feedback. 3D animation videos with embedded assessments will be created for four surgical procedures, namely: open appendicectomy (OA), mastectomy and axillary clearance (Mx & ANC), below-knee amputation (BKA) and inguinal hernia repair (IHR).

Analysis stage

The analysis stage sought to provide an understanding of the current situation and the gaps that must be filled with regard to surgical procedure training. This was carried out as outlined below:

Problem identification: There is increasing concern in the literature about the inadequacy of the traditional teaching method for surgical procedure cognitive skills under the apprenticeship training model [91-94]. Surgical procedure cognitive skills are described as the ability to make critical decisions before, during and after a surgical procedure. It is a core competency for surgeons[67, 68]. The literature suggests the following reasons for the inadequacy of the traditional teaching method in covering surgical procedure cognitive skills:

- limited time for teaching cognitive skills in the operating room,
- ethical concerns[41, 42],
- dependency on available clinical opportunities [22, 23, 42], and
- unconscious competence[22, 23] limits cognitive skills transfer from experts to novices when teaching is carried out in the operating room.

Consequently, the traditional method of teaching surgical procedures may be producing surgeons who are not fully competent in cognitive decision-making. Therefore, there is a need for a teaching method that covers surgical procedure cognitive skills in a reproducible, systematic, and sequential approach to address the inadequacy of the traditional teaching method. Currently, very limited research has investigated reproducible, systematic and sequential methods of teaching cognitive skills for surgical procedures[42, 44]. The assumption is that teaching surgical procedure cognitive skills would lower surgical morbidity and mortality rates and consequently improve surgical outcomes [67, 68, 91, 94]. Therefore, the literature

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suggests a systematic and sequential approach to teaching surgical procedure cognitive skills. The following broader scope of topics for teaching surgical procedure cognitive skills was recommended: introduction, indications, contra-indications, pre-operative preparation and illustration of the technique (positioning, exposure, operative steps, closure, postoperative management, and complications) [22, 42, 95]. The researcher conducted a learner needs assessment survey to determine the following:

First, whether learners thought there was a need to develop a systematic and sequential method for teaching surgical procedure cognitive skills.

Second, whether they considered covering all the topics for a surgical procedure relevant and to what extent they wanted each topic to be covered.

The survey questionnaire form that was used is shown in Appendix 1.5. The questionnaire was modelled using closed-ended questions in the form of multiple-choice questions and a Likert-type scale to facilitate data entry and analysis[96]. The researcher acknowledges the limitation of this kind of questionnaire, especially since respondents cannot elaborate on their answer but considered it the best fit for this study. The survey was conducted to give surgical trainees a degree of choice and a voice. It was conducted online using the Moodle survey tools. The survey results were captured on the Moodle backend database and accessed under the participant's grade book. All participants indicated a need to develop a systematic and sequential method of teaching surgical procedure cognitive skills. Table 2.1 shows the survey results. Participants unanimously indicated that operative steps should be covered in detail. Additionally, over 90% indicated that pre-operative preparation, postoperative management, and complications should be covered in detail.

Table 2.1 Needs assessment questionnaire results.

	Relevance		Extent of coverage	
TOPICS	Yes	No	Detailed	Brief
Introduction	23	0	11 (47.8%)	12 (52.2%)
Indications	23	0	18 (78.3%)	5 (21.7%)
Contra-indications	23	0	11 (47.8%)	12 (52.2%)
Pre-operative preparation	23	0	22 (96.7)	1 (4.3%)
Positioning	23	0	11 (47.8%)	12 (52.2%)
Exposure	23	0	15 (65.2%)	8 (34.8%)
Operative steps	23	0	23 (100%)	0 (0%)
Closure	23	0	10 (43.5%)	13 (56.5%)
Postoperative management	23	0	21 (91.3%)	2 (8.7%)
Complications & management	23	0	21 (91.3%)	2 (8.7%)

1) The goal of the design: The goal of the instructional design was:
    a. To find out whether the digital teaching method led to better knowledge gain and retention compared to the traditional teaching method, and

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b. whether the digital teaching method was favoured based on participants' satisfaction level and procedure clarity.

Therefore, during Phase II the effectiveness of the digital teaching method was compared to the traditional teaching method regarding knowledge gain, retention, satisfaction level and surgical procedure clarity.

Design stage

During the design stage, an outline of a learning intervention was created and mapped. The learning intervention was the digital teaching method of surgical procedure cognitive skills. The digital teaching method was to be designed using 3D animation videos and embedded continuous assessments yielding an educational video.

The educational videos consisted of two main parts: an introductory slide presentation and a 3D animation illustration of the steps of a surgical procedure. Each of the two components of the educational video had sub-topics, and the outline is provided in Figure 2.2. The educational video proceeded in the direction of the arrows, as shown in Figure 2.2. The location of the embedded assessments in the educational video timeline is shown as quizzes 1-3. The educational video was developed following the 3D animation video production process defined under the section called Definition of terms, models and processes in Chapter 2. The development process is presented in the development stage of the ADDIE model in the next section.

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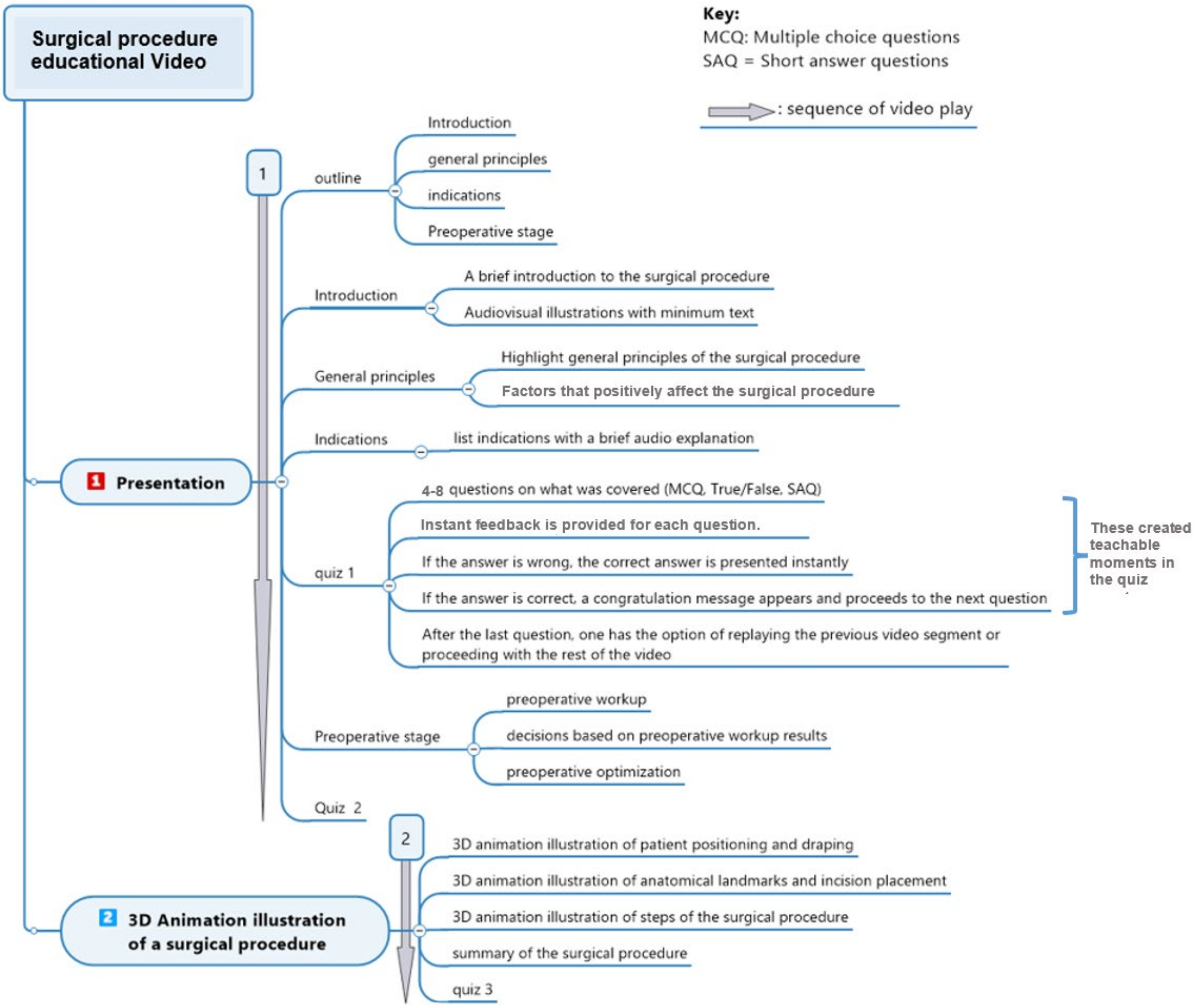

Figure 2.3 The outline and mapping of the educational video.

The digital teaching method for surgical procedure cognitive skills was delivered in a video format. The educational videos for surgical procedure cognitive skills were availed to participants online through an LMS.

Development

During this stage, 3D animation videos were developed, followed by creating and embedding continuous assessments in the educational video. A run-through of the complete education video was conducted.

1) 3D animation video production.

The 3D animation videos for teaching surgical procedure cognitive skills were produced following the three main stages for the production process of 3D animation videos: pre-production, production and post-production processing. The process was adapted to the researcher's available resources and animation style. This chapter elaborates on the 3D animation video production process explained in the section ‘definition of terms, models and processes. Its explanation is also available as a video at https://youtu.be/0ZzaDxJk5oM

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Pre-Production

Ideate / The Idea. The traditional method of teaching surgical procedures covers surgical procedure cognitive skills inadequately[8, 21-23]. There is a need to develop new teaching methods for teaching surgical procedure cognitive skills. The idea was to design an alternative digital teaching method for surgical procedure cognitive skills using 3D animation videos, with embedded continuous assessments and linked instant feedback creating further teachable moments. The teaching resource was hosted on the University of Botswana's Moodle LMS. During the pre-production stage, the idea was developed through several processes: the storyboard, animatic and previsualization, design and modelling, rigging, texture, layout, animation, and lighting and rendering. These are considered individually.

a) Storyboard. The educational video produced using 3D animation consisted of two components, the introductory slide presentation and the 3D animation illustration of the surgical procedure.

The steps followed during the storyboarding are outlined below. The storyboarding for the introductory slide presentation was created using Microsoft PowerPoint. The brief introductory slide presentation was reviewed with departmental colleagues and Supervisors. The Supervisors approved the introductory slide presentation for the four surgical procedures after multiple iterations and refinements. Two to three quizzes with 4-8 questions (MCQ, Fill in the blank, True/False) were created regarding critical points of the presentation that needed emphasis and were quality checked by four subject matter experts in the Department of Surgery. Members of the Department of Surgery have formal training as Assessors and Moderators. The researcher received formal training from the Department of Medical Education at the University of Botswana and from a private consultancy. The training led to the researcher acquiring a level 8 NQCF accreditation certificate as an Assessor and Moderator by the Botswana Qualifications Authority. See the attached certificates of full registration and accreditation under appendix 2.5 and 2.6. The storyboard for the 3D animation illustration of each surgical procedure was also created using Microsoft PowerPoint. The technical steps of each surgical procedure were outlined in a PowerPoint presentation. The operating room setup, camera positions, and lighting were described. The presentation was reviewed with four colleagues in the Department of Surgery and my Supervisors. After multiple reviews and refinements, a final PowerPoint presentation was approved. One to two quizzes with 4-8 questions (MCQ, Fill in the blank, True/False) were created regarding critical points of the 3D animation illustration that needed emphasis.

The two PowerPoint storyboards were merged into one storyboard representing an educational video. Slides of the first part of the merged presentation that could be reduced to audio with mostly pictures or illustrative 3D animation video clips were identified. Placeholder sketches for the video clips and pictures were made on the PowerPoint slide content area, and the audio script was on the notes area of the slide. Slides of the second part of the merged presentation were reduced to placeholder animation sketches, and the audio script was stored in the notes area of the slides.

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b) Animatic and Previsualization. Camtasia® software was used to generate the animatic of the whole presentation. Camtasia® can record the computer screen during a PowerPoint presentation and also record the presenter through an input microphone producing a video with an audio overlay. The animatic video acted as a blueprint for educational video production. It helped determine how much actual animation needed to be produced.

c) Design & Modelling. The operating room, theatre table, trolley, lights, surgical tools, drapes, the surgeon, and the patient were created through 3D modelling and computer sculpting. Autodesk® Maya 2020, 3DS Max™ 2020 and Zbrush™ 2020 software were used for 3D modelling. Zbrush™ 2020 was used mainly for organic modelling and sculpting. Zbrush™ 2020 works the same way as one would when moulding a human figure from a ball of mud. Computer sculpting is an extensive back-and-forth process which starts with a primitive shape, such as a sphere or box, which is then beaten down and built up repeatedly to the desired shape. The final structure was refined using high-resolution sculpting to add detail. The final product was then exported to another software, Autodesk® Maya 2020, where the next rigging process was carried out. Rigging means adding the bone system to a model so that it can be manipulated during animation. The researcher also used Autodesk® Maya 2020 software to produce hard-edge models using box modelling. These models included theatre tables, surgical tools, and trolleys. The process also starts with a primitive shape, such as a box or sphere, and its hard edges and faces are pulled in and out to the desired shape of the model. Finally, the box model was refined at high resolution.

The modelling process is an iterative process involving the use of two or more software programmes to achieve the final functional product that can be animated in a more realistic way. A sample of the 3D models of a male patient and other operating room equipment is shown in Figure 2.3 below.

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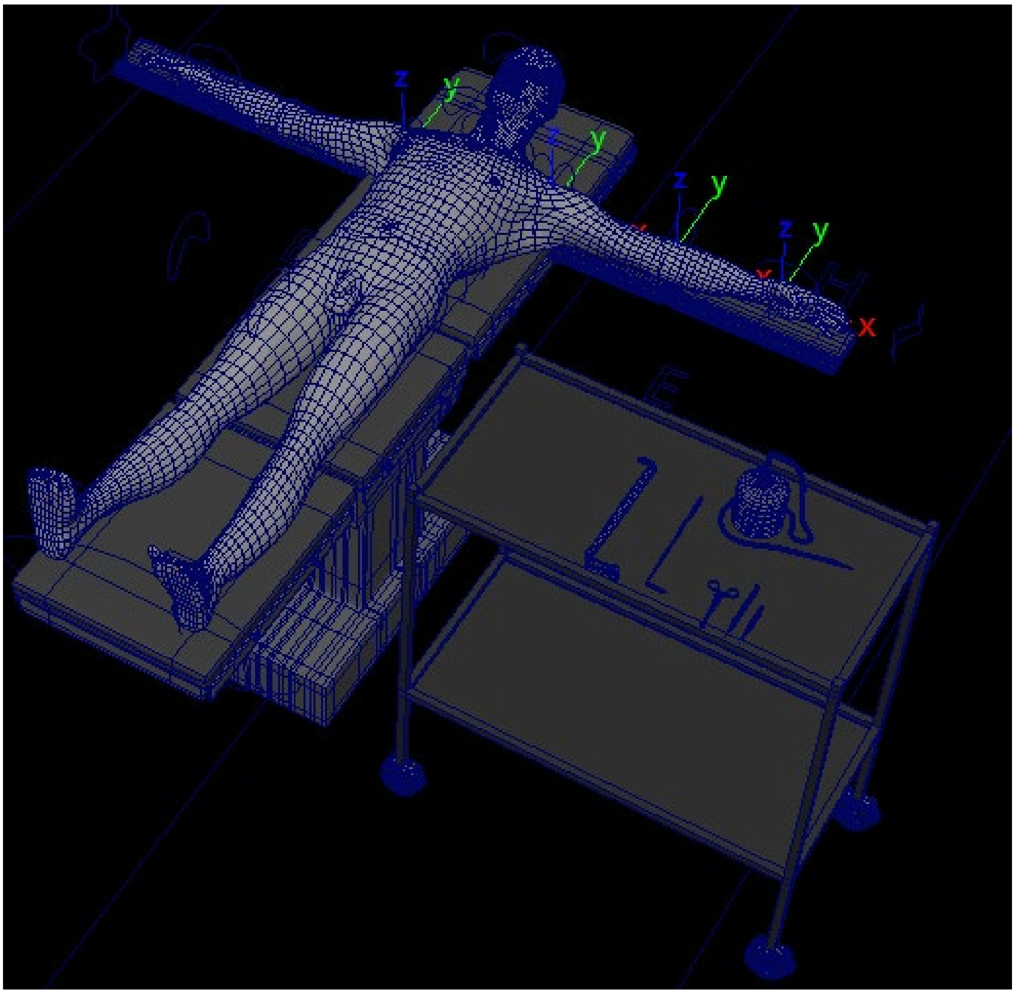

Figure 2.4 3D model of a patient and other operating room equipment.

d) Rigging. After completing the modelling of characters and scene objects, the models were rigged using bones and other rigging systems to allow their manipulation during animation. This involved creating a bone system within the model and assigning parts of the body to corresponding bones in the human model. The result is a skeletal system that moves body parts as in real life. A similar rigging system is available for solid-edge models such as theatre tables. For instance, the system allows the table to be rotated, tilted, or elevated. Figure 2.4A shows a rigged patient model with bone elements used to flex (Figure 2.4B) at the knee in the subsequent picture. The bone rigging systems can be seen through the solid patient model. The rigging process is a time-consuming iterative process involving a back-and-forth fine-tuning of bone influences on the body or model parts. The objective is to achieve realistic movements of the models during animation finally.

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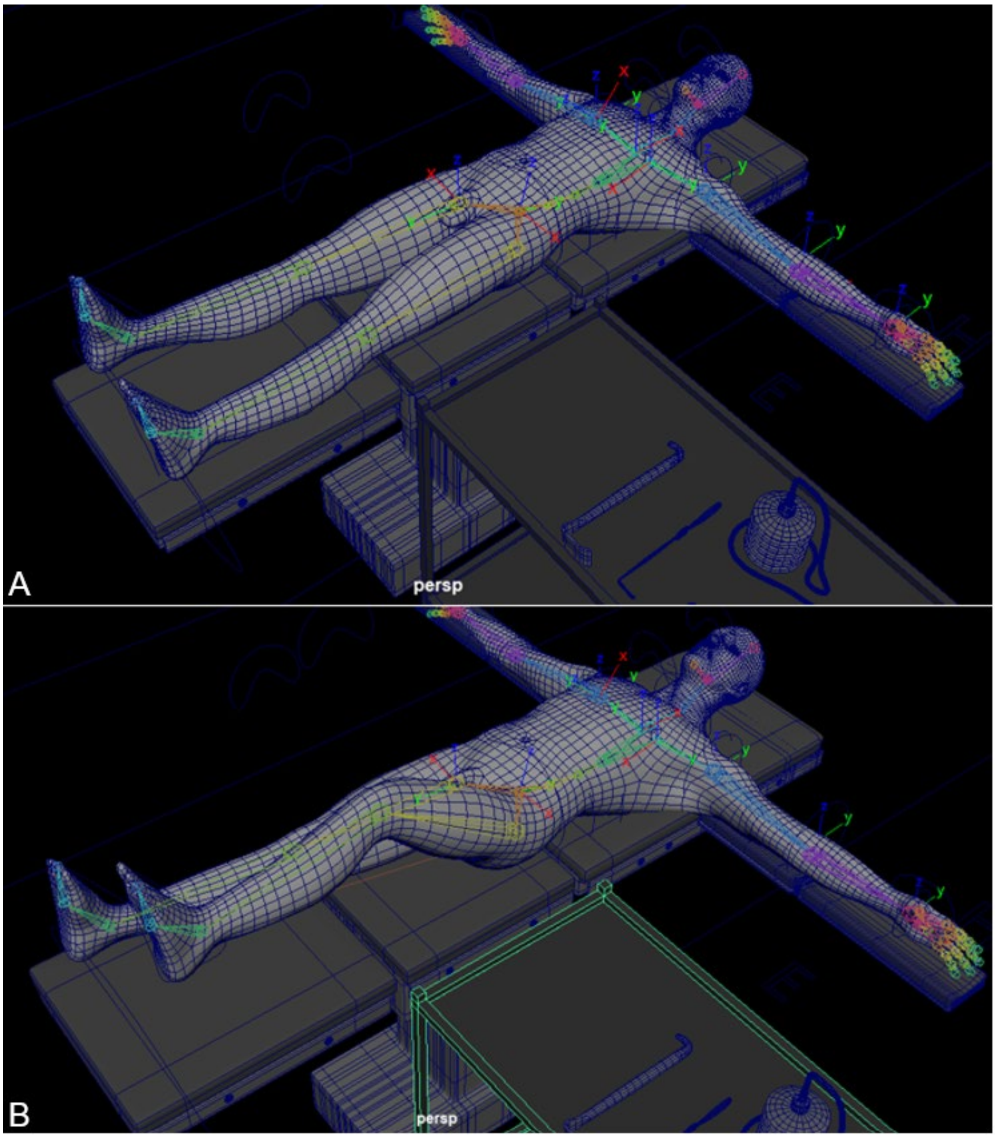

Figure 2.5 A rigged patient with bone elements flexing at the knee.

e) Texturing. Digital models were textured to give them a realistic appearance. The texture maps were extracted from the models using 3D modelling software (Autodesk® Maya 2020, 3DS Max™ 2020 and ZBrush™ 2020) as 2D Maps and exported to Photoshop™ 2020 for texture painting. Extracting texture maps of 3D models is almost like peeling off and flattening the skin of the parts of the 3D models and exporting it to a 2D graphics software to colour in a more realistic texture and colour. Texturing and colouring were done on Adobe® Photoshop 2020 software. The complete 2D texture maps were then reimported and reapplied to the 3D model. A back-and-forth corrective and fine-tuning of the texture map resulted in a more realistic map. Figure 2.5 demonstrates the 2D texture map and the patient model with the 2D texture map applied. Note that the operating room equipment also looks more metallic and realistic because the textured materials were applied. It took me two days to arrive at the final refined texture of a human model.

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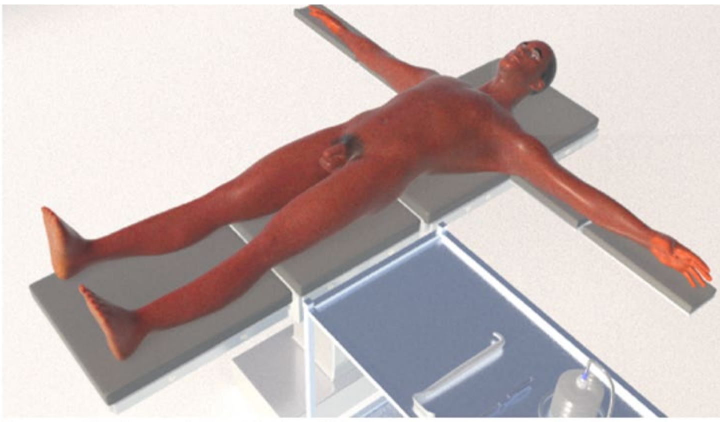
A) 2D patient texture map.



B) The patient model with the 2D texture map applied

Figure 2.6 2D texture map and the patient with an applied texture map.

The pre-production process took two months to complete all the required models. The production stage is presented in the next section.

Production:
The production stage started with preparing the animation stage through 3D animation to the output of the final product as a video. It consists of the following substages: the layout, animation, lighting and rendering. The substages are explained next.

a) Layout. A scene was set up as per the specific surgical procedure. All required models, such as the patient, surgical tools, surgeon, and anaesthetic equipment, were loaded on the scene. Cameras were positioned to create a complete composition for the researcher to animate. Figure 2.6 shows the operating room layout setup with the 3D models. This is a realistic virtual environment with objects casting shadows and the patient being able to move after rigging. Figure 2.7 shows the layout after the draping of the patient in the operating room.

Figure 2.7 Operating room layout with 3D models.

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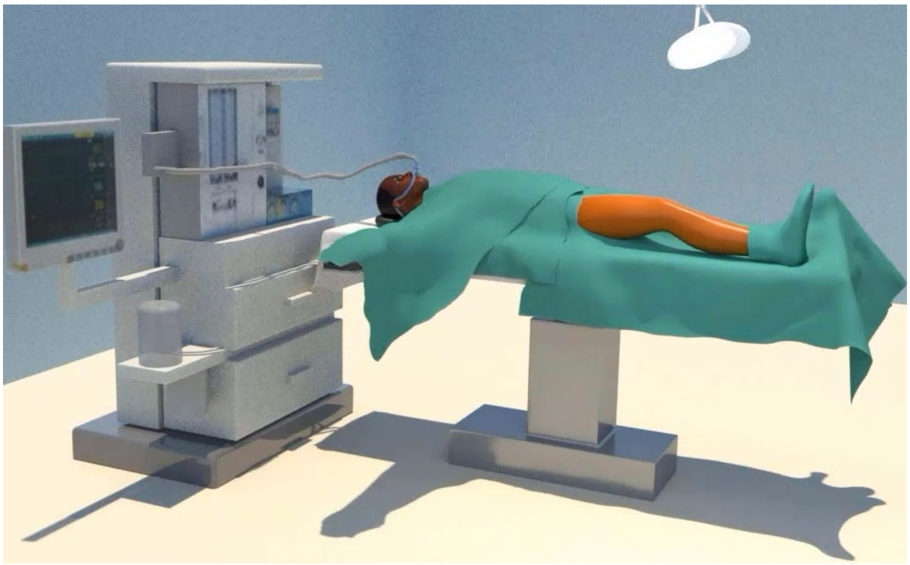

Figure 2.8 Patient in the operating room after draping.

b) Animation. The researcher used the rigged 3D models to create motion by manipulating it and storing sequential poses of the model over the software timeline until a complete action was achieved. Furthermore, I used advanced sub-model element animation to achieve the more organic refined parts of the animation of the surgical procedure. The sub-model element animations included vertex, face and edge animation systems. All steps, from the positioning of the patient through to skin incision, access, tissue manipulation, closure and surgical wound dressing, were animated. Autodesk® 3D Studio Max and Autodesk® Maya 2020 software were largely used for animation. Multiple shots of individual surgical procedure steps were animated, refined, and output as video. These were later merged into one surgical procedure animation scene. For one surgical procedure animation, up to 30 shots were animated, refined, and output as video over a period of one month. The shots were finally composited into a single scene showing the whole surgical procedure technique. Figure 2.8 shows snapshots of the animation of the skin incision for the below-knee amputation procedure. One can appreciate the bleeding incisions and the markings for the incision placement. The gloved surgeon's hands, the blade, the leg and the drapes are all 3D models that were rigged and textured to look realistic.

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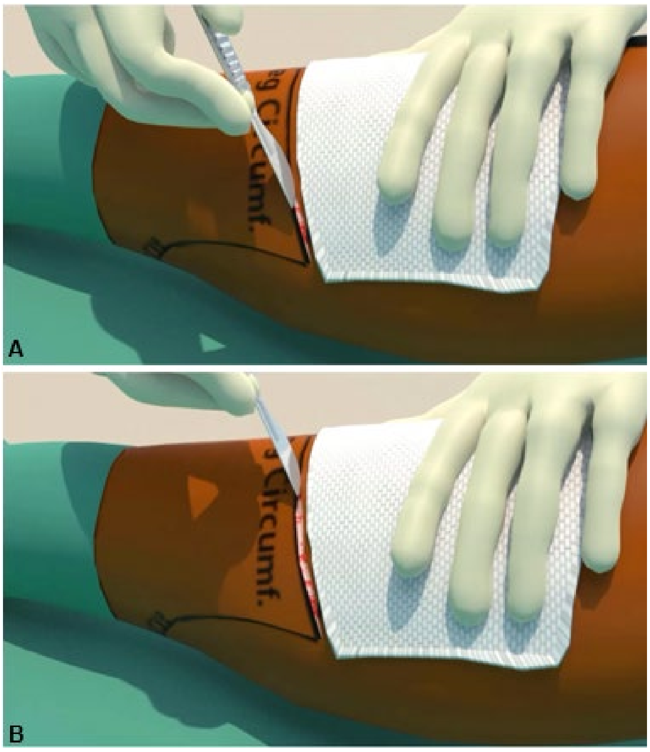

Figure 2.9 A snapshot of skin incision animation.

c) Lighting / Rendering. Scene lights were adjusted to the desired final render. The light intensity, focus, position and even the type of light source were chosen to suit the desired scene appearance. The lights were virtual and could be deployed onto the scene from the 3D animation software. The software can adjust the light source's attributes to the desired appearance. The shadows cast by models in the ab've figure are computer generated and result from an adjustable attribute on the light source. The final product of the animation was output as a video, ready for post-production processing and enhancement.

Post-Production:
Final finishing touches were added to enhance the video. This included image enhancement and colour correction, which was done using the Adobe® AfterEffects software. Sound and audio overlay was added to the video using voice-over recording on Camtasia® software. The pace of the animation was also adjusted on Camtasia® to optimise learning. An audio overlay of the introductory slide presentation was added and synchronised with the 3D animation scene for the best impact. The audio was further edited by removing background noise, adjusting the volume, and editing out unwanted parts in Camtasia®. To complete the educational video, the sketches in the introductory slide presentation part of the educational video were replaced with illustrative pictures and 3D model renderings. Figure 2.9 shows some of the slides of the presentation part for the below amputation with illustrative 3D models and images inserted to replace sketches.

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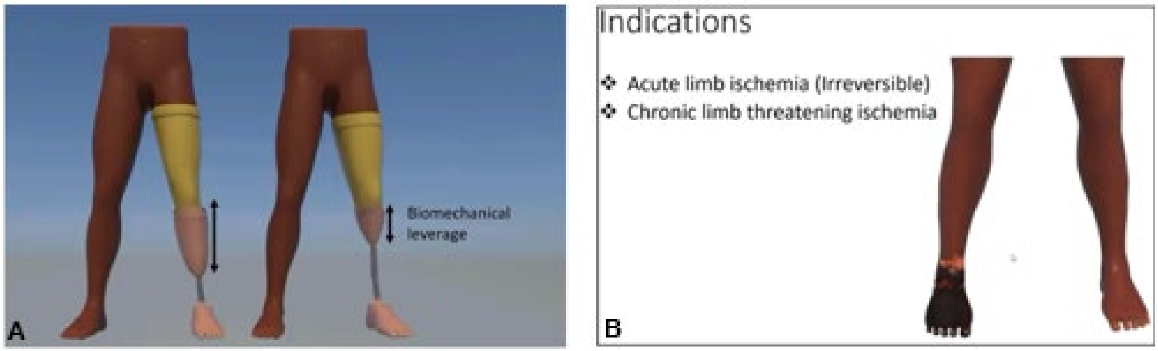

Figure 2.10 snapshots of the presentation part of the video with illustrations.

After the refinement, the final product was output as a complete educational video for surgical procedure cognitive skills training. Snapshots from the educational video for below-knee amputation are shown in Figure 2.10.

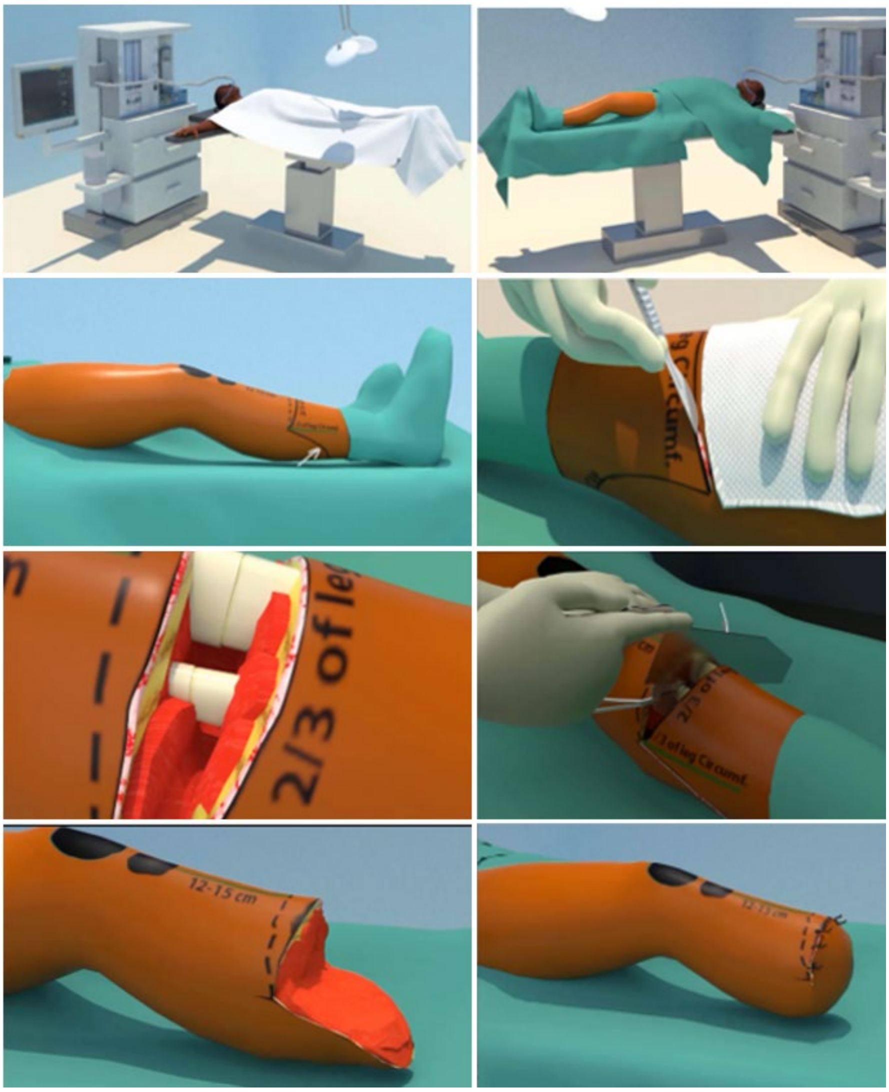

Figure 2.11 Snapshots of the educational video for below-knee amputation.

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2) Assessments development

The educational video had embedded assessments linked to instant feedback to support learning. The design of the continuous assessment questions aimed at assessing levels 1-5 from the six levels of Bloom’s Taxonomy of the cognitive domain. This meant the questions assessed the participants’ remembering, understanding, application, analysis and evaluation abilities using multiple-choice (MCQ), True/False and Fill in the blank. The ability to embed MCQ, True/False and Fill in the blank tasks with instant feedback was made possible by using the Camtasia® quiz tool. The questions were quality-checked and moderated by four members of the Department of Surgery for their appropriateness for the level of assessment. As part of the University of Botswana quality assurance initiative, all academic staff receive formal training from the Department of Medical Education and other certified bodies for their accreditation as Assessors and Moderators. The researcher did the university course and attended the same course offered by a private consultancy. The Botswana Qualifications Authority (BQA) subsequently accredited the researcher as an Assessor and Moderator and awarded NCQF Level 8 certificates provided under Appendix 2.5 and 2.6. The training includes levels of cognitive skills and their assessment using learning taxonomies such as Bloom’s taxonomy, Miller and SOLO, among others. Outcome-based approaches to teaching, such as constructive alignment, form part of the training. Academic staff apply the skill every year during the creation and moderation of final-year examinations. Each educational video for cognitive skills of a surgical procedure had a series of quiz events embedded throughout the educational video. Each component question in the quiz events was linked to immediate feedback. They were mapped and confirmed on the taxonomy by an educationalist. The following conditions were to be implemented for the embedded continuous assessment events:

a) Assessments were to be interspersed between a set of topics within the educational video.

b) Each educational video for the four surgical procedures was to have at least three such assessment events, each containing 4-8 questions.

c) Embedded questions were set in an adaptive release model. Adaptive release is achieved by making course content on an LMS available to students only when they have fulfilled certain criteria.

d) The participant had to complete watching the preceding educational video segment before an assessment event was made available.

e) Additionally, the participants needed to answer all the questions to watch the next segment of the educational video. Therefore, they could not skip an assessment event and continue watching the rest of the educational video.

f) The candidate needed to score 75% or more for each embedded assessment event to proceed to the next educational video segment; otherwise, they were to review the preceding topic.

g) Participants could revisit the viewed segments of the video.

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h) On answering the embedded assessment questions, the participants received instant feedback, providing the correct answer and explaining the rationale for the answer, creating another teachable moment.

i) The LMS learning analytics captured the completion of watching the educational video, which also implied that the participant scored more than 75% for each embedded assessment event. The instant feedback functionality linked to each question in the embedded assessment events was achieved using the Camtasia® software quiz tool shown on the snapshot of the software in Figure 2.11. This tool allows one to create three types of questions: MCQ, True/False, and Fill in the blanks, as shown on the annotated snapshot. It also provides the following options for each question:

   i) Ability to set the correct answer for all types of questions.

   ii) Ability to instantly display feedback when the answer is correct or wrong.

   iii) An option to choose an action after answering, as shown on the snapshot. These options were:

      - Continue to the next question
      - Go to a URL
      - Jump to a point in the timeline

Figure 2.12 Snapshot of Camtasia® software showing the quiz tool and timeline.

Thus, the educational video was used as the digital teaching method for surgical procedure cognitive skills in the Moodle course. Therefore, an educational video was produced for each of the four surgical procedures. Figure 2.12 shows an annotated snapshot of the complete educational video for mastectomy and axillary node clearance, with the location of embedded assessment events shown along the video timeline.

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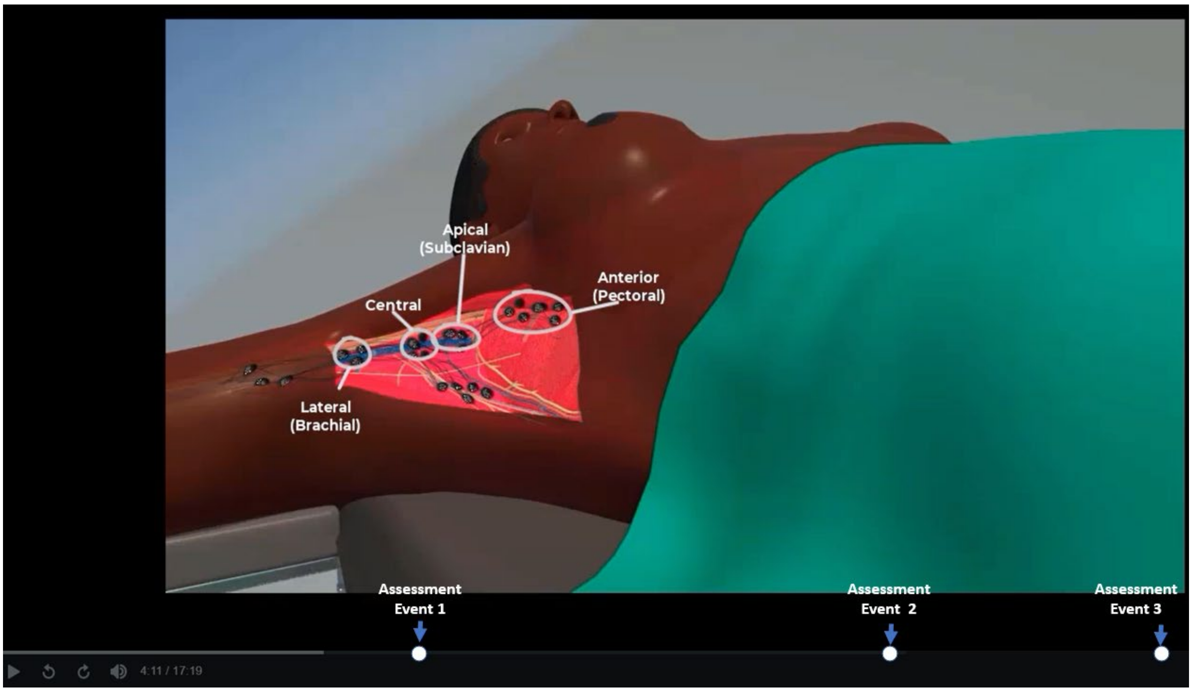

Figure 2.13 Snapshot of the educational video showing assessment events.

The educational video production process required the use of eight software programmes. Although I had used most of the software before, the complexity and size of this project required me to learn new techniques for using the software. Learning such techniques involved a steep learning curve. The final product was an interactive educational video which lasted 17 minutes or less. It took me approximately a month to produce one educational video. The educational videos for the four surgical procedures took four months. In future, an improved familiarity with the software will probably decrease the production time by about 30%. In addition, the time taken to produce an educational video was getting shorter with each subsequent production process.

3) Conduct a run-through.

The four educational videos were reviewed with the Supervisors and three members of the Department of Surgery and approved. Two senior residents tested the videos and the embedded assessment events. The following review comments and amendments were made: minor clerical errors were picked in the assessments and were amended, and distracting background noise was also identified and edited out using Adobe® audition software.

Four educational videos were completed to teach surgical procedure cognitive skills. Thus, the digital teaching method was produced using 3D animation videos and embedded continuous assessments with instant feedback. The design of the LMS course layout and the uploading of the educational videos on an LMS will be discussed under Phase II. This is because the layout design needed to conform with the crossover repeated measures study design used for comparing the digital and traditional teaching methods. The comparison occurred during Phase II, the evaluation stage of the ADDIE model.

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Implementation
The Supervisors approved the educational videos for the four surgical procedures. The educational videos were ready for uploading after the LMS layout design during the study's evaluation stage (Phase II). The evaluation stage was conducted solely online.

The researcher chose to deliver the course on Moodle^{TM} LMS in a course format. Moodle is the official LMS used by the University of Botswana. In addition, the university recommends using local but not alternative platforms for one to receive full support from its Information and Technology (IT) department.

The researcher applied for permission to create a course on the University of Botswana's (UB) Moodle LMS. The notification by the University of Botswana Information and Technology department that the course was created on Moodle and that the researcher was given the teacher role is attached under Appendix 1.1. Additionally, the researcher sought permission to enrol non-UB student candidates on the course. The University of Botswana's Information & Technology department granted the permission as per the communication mentioned earlier.

Phase II of the study was conducted during the last stage of the ADDIE model, the Evaluation stage.

2.2.2 **Phase II: The evaluation stage of the ADDIE model**

The evaluation stage of the ADDIE models was conducted during Phase II of the study. It involved comparing the digital and traditional teaching methods regarding knowledge gain, satisfaction level, and procedure clarity. The comparison of knowledge gain used pre- and post-tests from which a differenced score was calculated as a measure of knowledge gained. Retention tests were also used to measure knowledge retention following each teaching method. The comparison of knowledge gained was carried out by using the repeated measures study design. A survey questionnaire was completed to assess satisfaction levels and procedure clarity. The satisfaction level and procedure clarity were compared on a 5-point Likert scale. Baseline information regarding the participants' demographics and computer proficiency was also collected using survey questionnaires. Participants also completed another needs assessment form. The decision to repeat the needs assessment was based on the fact that more healthcare centers were included, and therefore, more participants were expected to take part, giving the results more statistical power.

Selection of Participants
Purposive sampling, a non-probability sampling method was used in this study. This sampling method was chosen because just a specific group of people could serve as primary data sources (surgical registrars and medical officers) due to the nature of research aims, objectives and design. Homogeneous sampling, a type of purposive sampling was used in that medical officers and junior surgical registrars in their first year of training were the target population. The members of this target population were at a similar level of function and exposure in surgical departments[97]. This sampling method allows generalisation only within the target population, but not to the entire population. The data collection in purposive sampling is relatively cost

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effective and time-saving. The data collected have a low margin of error. Due to the nature of the study and the target population, this was the most appropriate sampling method[98, 99].

Developing questionnaires and tests.
The consent form and other questionnaire forms were developed using the Moodle feedback resource. The designed consent, demographics, computer proficiency, needs assessment, and satisfaction level & procedure clarity forms are shown in Appendix 1.2 – 1.6. The computer proficiency assessment form was adapted and adopted from the computer proficiency questionnaire (CPQ-12), a validated and approved tool for training and research purposes [90].

A question bank with four categories of questions according to the four surgical procedures was created. Each category had questions assessing five of the six levels of Bloom's taxonomy. The questions were reviewed and quality-checked by members of the Department of Surgery using an assessment blueprint that was designed based on the levels of cognitive domain in the Bloom's taxonomy. The blueprint contained a guide on sections, content, cognitive levels to be assessed, distribution of questions in each level of the cognitive domains, and number of questions per section[100]. The same process used during the design of questions for the embedded assessments was followed. The questions from the question bank were used to constitute the tests (pre-, post-, and retention tests) in the Moodle course layout. The link for the traditional teaching method in the Moodle course layout was populated with instructions for the participant to prepare for their allocated surgical procedure in the same way they would when preparing to do or assist a surgical procedure in the operating theatre. In the traditional teaching method, it is up to the trainee to study for the surgical procedure before attending it. The preparation, more often than not, means reading a textbook. The participant was instructed to complete the post-test soon after they felt ready and satisfied with their preparation.

The researcher tested the Moodle course layout and setup for conformity with the repeated-measures crossover study design. The final product was presented to the supervisors for review, and refinements were made. Three such presentations were made, and the following refinements were suggested:

a. Collapsing the homepage to the level of Sections for it to look less busy.
b. To make it possible for the participants to indicate their confidence level for all the answers they give in all tests.
c. All tests are to be restricted to a single attempt.
d. Not to give participants their scores for their pre-test, post-test, and retention tests. This was to maintain the integrity of the subsequent tests since the questions came from the same question bank. However, their marks were provided once all tests were completed.

The researcher amended the above using Moodle's existing functionalities.
A final run was made using two senior residents and two members of the Department of Surgery. No errors were found, and the project was approved for implementation. A video demonstrating the Moodle course layout with uploaded content and the adaptive release implementation is provided at this link:

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https://youtu.be/X_HhXBp15RU. The online project was removed from the test mode to the implementation mode.

The enrolment of participants was started, and they were given user credentials to log into the University of Botswana Moodle LMS. The participants were introduced to the study and the Moodle interface at enrolment. The participants who consented to participate in the study completed the online consent form. However, if a candidate wanted to have access to the digital teaching method without participating in the study, they were registered and given login credentials with a non-participant status. Access was only given to them after the completion of the study to avoid contamination of the study findings. The completion of the online consent form was followed by the assignment of surgical procedures ('a' and 'b') to participants and study groups A and B based on their enrolment position as described in the study procedure. Participants then completed the demographics, computer proficiency, and needs assessment questionnaires. Each participant then scheduled their dates for study periods 1 and 2. The researcher implemented the Moodle course access control restrictions and assigned participants to groups, including their planned study activities. The researcher tracked participants' progress through Moodle's participant log history system.

Explanation of the crossover-repeated measures study design

Each participant made two random draws from a container with the names of four surgical procedures. The first draw corresponded to procedure 'a' and the second draw to procedure 'b'. Participants were then randomly assigned to two groups (Groups A and B) according to their position in the enrolment order (1 – nth position). Group A consisted of odd-number positions (1, 3, 5, 7), and Group B had even-number positions (2, 4, 6, 8). Each participant in each group (A and B) was subjected to both the traditional and the digital methods of teaching the surgical procedures cognitive skills in a cross-over repeated measures design. During the repeated measures study design, the first intervention (period 1) for group A participants would be the traditional teaching method, while for group B, it would be the digital teaching method. The result of this modification would be that half of the participants would start with one teaching method while the other half would start with the other teaching method. This study design modification balanced out any advantage resulting from one teaching method being the first intervention. For each participant, the cognitive skills of procedure 'a' were covered during the first teaching method (period 1) and procedure 'b' during the second teaching method (period 2). This ensured that different content was taught and assessed at period 1 and period 2 (procedures 'a' and 'b'), minimising the carry-over effect. The diagrammatic representation of the crossover repeated measures study design is shown in Figure 2.14.

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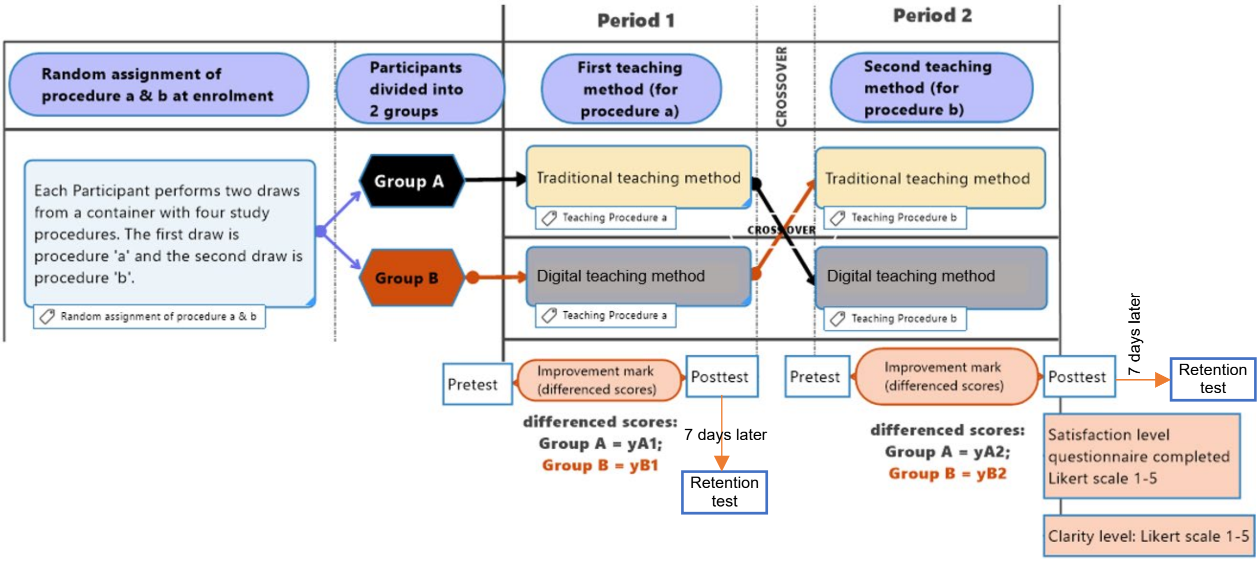

Figure 2.14 A complete representation of Phase II study design.

A pre-test was completed before the two teaching interventions (traditional and digital teaching methods), and a post-test was completed after each. The differences between the post-test and pre-test marks in periods 1 and 2 were called the differenced scores. The knowledge gained was measured using the differenced score. The differenced score was determined for both the traditional and digital teaching methods for everyone. This allowed the comparison of the differenced score for the two interventions for everyone. Two weeks after the post-test, the participants completed a retention test. After the participants were exposed to both teaching methods, they were required to complete a questionnaire on satisfaction level and procedure clarity using a 5-point Likert scale.

The evaluation phase of the study was conducted on Moodle using a Moodle course layout that is tailor-designed to implement the study design. Because the study was solely administered online, the Moodle course layout needed to factor in the study design. Adaptive release and sequencing of teaching and assessment resources were important. These included educational videos with embedded assessments, tests for assessing knowledge gain (pre-tests, post-tests and retention tests), and survey questionnaires for assessing satisfaction and procedure clarity. The adaptive release was achieved by making course content on Moodle available to students only when they had fulfilled certain criteria. Moodle functionalities were used to sequence and selectively restrict access to learning resources. Access to the course was controlled through unique user login credentials. Each participant had login credentials, which were given to them at enrollment. The Moodle course layout consisted of the following sections to enable the full online implementation of the study:

a. General section. The introductory study information was made available under this section. At enrolment, the researcher also introduced the study to candidates.

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b. Informed consent section. The consent form was provided under this section for online signing.

c. Demographics, computer proficiency, and needs assessment sections contained questionnaires for online completion.

d. Candidate assignment to study groups (A or B) and allocation of procedures a & b were conducted at enrolment and documented online. Teaching and learning resources for the two teaching interventions and assessments (pre- and post-tests) were sequenced in the following order:
   i. Pre-test
   ii. Intervention (digital teaching / traditional teaching method)
   iii. Post-test
   iv. Retention test

e. The satisfaction level and surgical procedure clarity questionnaire were completed online under the corresponding sections.

Below is the outline of the layout of the study content on the Moodle course for online administration.

- Executive summary
- The problem statement, hypothesis, aims and relevance.
- Participant's information and informed consent
- Registration form (electronic form)
- Demographics questionnaire (survey)
- Computer proficiency questionnaire (survey)
- Needs assessment questionnaire (survey)
- Open appendicectomy
  - Pre-test (quiz)
  - Intervention 1 or 2 (digital teaching / traditional teaching method)
  - Post-test (quiz)
  - Retention test (after two weeks) (quiz)
- Mastectomy and axillary clearance
  - Pre-test (quiz)
  - Intervention 1 or 2 (digital teaching / traditional teaching method)
  - Post-test (quiz)
  - Retention test (after two weeks) (quiz)
- Inguinal hernia repair
  - Pre-test (quiz)
  - Intervention 1 or 2 (digital teaching / traditional teaching method)
  - Post-test (quiz)
  - Retention test (after two weeks) (quiz)
- Below knee amputation
  - Pre-test (quiz)
  - Intervention 1 or 2 (digital teaching / traditional teaching method)
  - Post-test (quiz)

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    - Retention test (after two weeks) (quiz)
- Satisfaction & procedure clarity questionnaire

The following Moodle functionalities were used to build the adaptive release of the learning resources to conform with the study design.

a. Restrict access. This functionality is associated with each content/resource (quiz, questionnaire, videos, etc.). It allows the designer to create conditional statements for the adaptive release of TLAs.
b. Grouping. This functionality controls access to learning resources based on the group a participant was assigned to. Table 2.2 shows grouping according to procedures 'a' and 'b' assigned at enrolment.

Table 2.2 Surgical procedure representation as per the study period.

Surgical procedure	Period 1 (a)	Period 2 (b)
1. Open appendicectomy	a1	b1
2. Mastectomy and axillary clearance	a2	b2
3. Inguinal hernia repair	a3	b3
4. Below knee amputation	a4	b4

For instance, if a participant was assigned group **a1b2**, it implied that they would be taught open appendicectomy during period 1 (**a1**) and mastectomy and axillary clearance during period 2 (**b2**) of the study design. Therefore, participants in this grouping would only have access to open appendicectomy during period 1 and mastectomy only during period 2. This was achieved by building conditional statements for accessing TLAs of a surgical procedure. A participant in group **a1b2** will be restricted from accessing inguinal hernia repair and below-knee amputation resources.

The functionalities mentioned above were used to implement the cross-over repeated measures study design.

The Moodle course was created on the University of Botswana's Moodle LMS. Placeholder content was used in place of the educational videos, tests and questionnaires while testing the layout functionality. The course layout was reviewed with Supervisors and tested. The snapshot of the course layout is shown in Figure 2.15.

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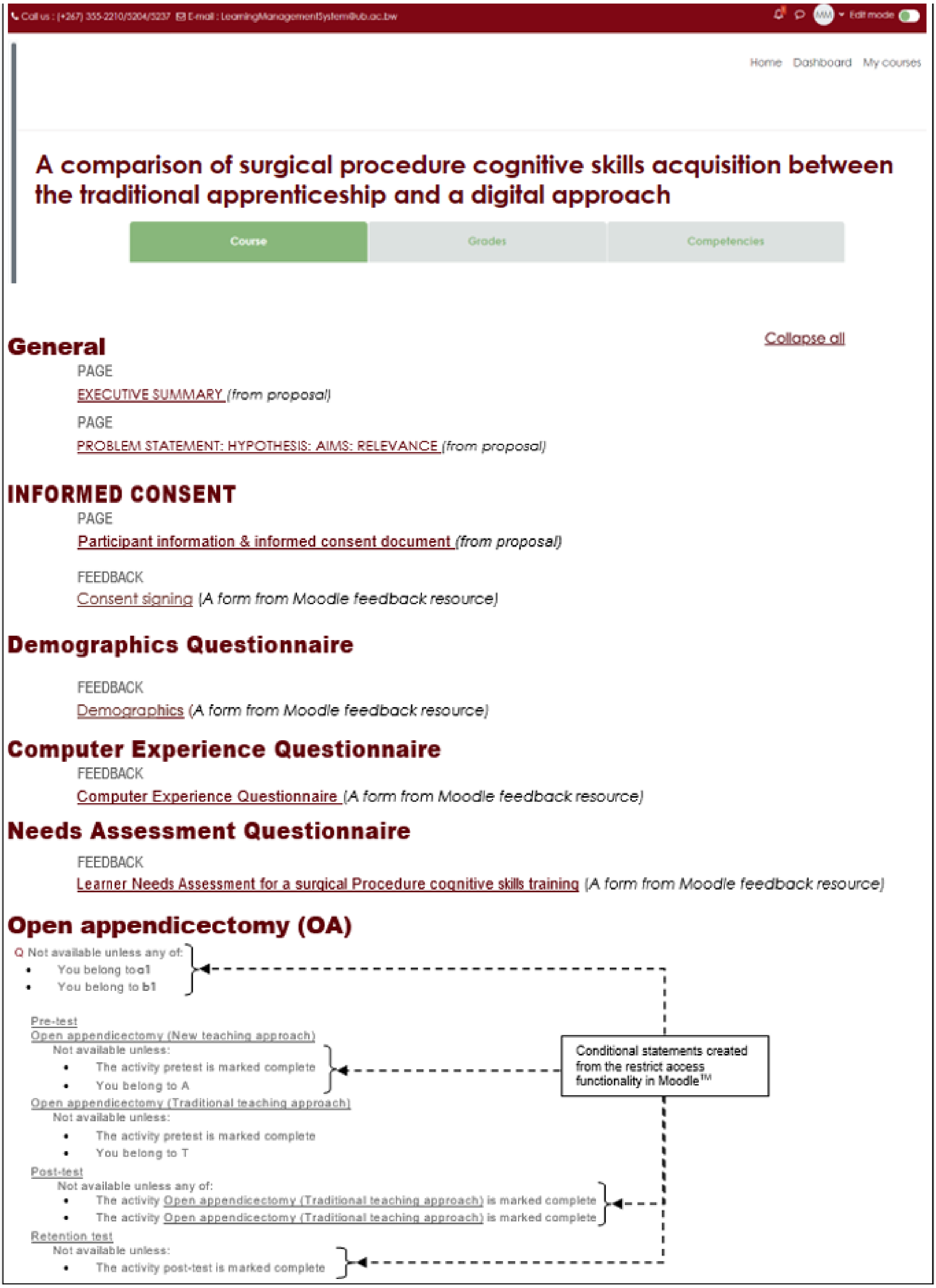

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Mastectomy and axillary node clearance

Not available unless any of:

- You belong to a2
- You belong to **b2**

Pre-test
Mastectomy and ANC (New teaching approach)
Not available unless:
- The activity pretest is marked complete
- You belong to A

Open appendicectomy (Traditional teaching approach)
Not available unless:
- The activity pretest is marked complete
- You belong to T

Post-test
Not available unless any of:
- The activity Mastectomy and ANC (Traditional teaching approach) is marked complete
- The activity Mastectomy and ANC (Traditional teaching approach) is marked complete

Retention test
Not available unless:
- The activity post-test is marked complete

Inguinal hernia repair

Not available unless any of:

- You belong to a3
- You belong to b3

Pre-test
Inguinal hernia repair (New teaching approach)
Not available unless:
- The activity pretest is marked complete
- You belong to A

Inguinal hernia repair (Traditional teaching approach)
Not available unless:
- The activity pretest is marked complete
- You belong to T

Post-test
Not available unless any of:
- The activity Inguinal hernia repair (Traditional teaching approach) is marked complete
- The activity Inguinal hernia repair (Traditional teaching approach) is marked complete

Retention test
Not available unless:
- The activity post-test is marked complete

Below knee amputation

Not available unless any of:

- You belong to **a4**
- You belong to **b4**

Pre-test
Below knee amputation (New teaching approach)
Not available unless:
- The activity pretest is marked complete
- You belong to A

Below knee amputation (Traditional teaching approach)
Not available unless:
- The activity pretest is marked complete
- You belong to T

Post-test
Not available unless any of:
- The Below knee amputation (Traditional teaching approach) is marked complete
- The Below knee amputation (Traditional teaching approach) is marked complete

Retention test
Not available unless:
- The activity post-test is marked complete

Satisfaction, clarity, and feedback Survey

Not available unless: You belong to **Sat & Clarity Survey**

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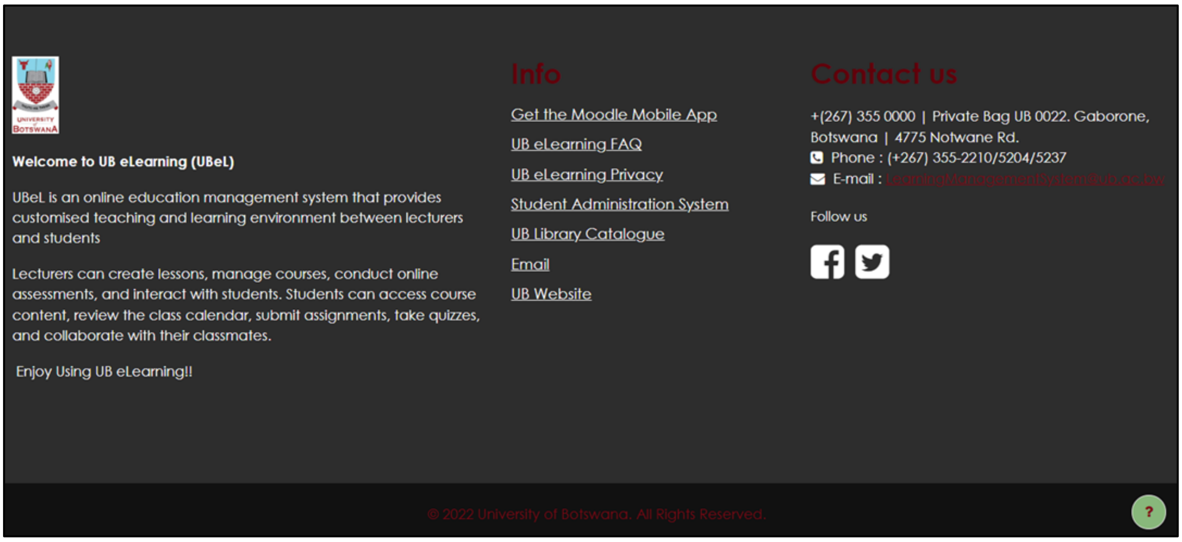

Figure 2.15 The online Moodle course.

Upon approval of the Moodle course layout design, the digital teaching method (the educational video) was uploaded to their respective place in the course. The following evaluation tools were developed and uploaded: questionnaires, pre-tests, post-tests and retention tests.

2.3 The Study procedure

This section covers the processes followed to accomplish the study objectives. It presents the study procedures for phase I and II of the study.

2.3.1 The Phase I study procedure

The digital teaching method for surgical procedure cognitive skills was designed using the first four stages of the ADDIE model of instructional design. After the design of the digital teaching method was completed, its effectiveness in teaching surgical procedure cognitive skills was compared to that of the traditional teaching method during the evaluation stage of the ADDIE model (Phase II of the study). During Phase II of the study, the cross-over repeated measures study design was used to determine the difference in knowledge gained using pre-, post-and retention tests. In addition, the trainee satisfaction level and surgical procedure clarity were compared on a 5-point Likert scale. The satisfaction level and surgical procedure clarity were assessed using a questionnaire hosted on the LMS (Moodle). Participants' baseline information regarding demographics, computer proficiency and need assessment was also collected using survey questionnaires. The entire study was conducted on the University of Botswana's Moodle LMS. The study procedure for Phase II is elaborated next.

2.3.2 The Phase II study procedure

The process of enrolment of participants was started. Candidates were introduced to the study's aim, objectives and methodology. The anticipated study duration, potential distress, risks and benefit were also discussed. Candidates were allowed to ask questions regarding the study. It was made clear that participation was purely voluntary and that no one would be victimised for non-participation or ending their participation during the study. Participants' autonomy was respected, and where they

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were considered to have diminished autonomy, they were protected. There was no monetary reward, coercion or undue pressure on the candidates. Candidates received a pamphlet containing the study aims, objectives and methodology. The pamphlet contained the researcher's contacts. At the end of the study's introduction, candidates who wanted to enrol on the study were requested to contact the researcher using the contact details provided in the pamphlets. Candidates were also informed that non-participants could request access to the digital teaching method after the study was completed.

Once candidates expressed their willingness to participate, they were introduced to the Moodle interface and enrolled. They were given user credentials to log into the University of Botswana Moodle LMS. Participants were anonymised in Moodle™. This was achieved through a setting on the Moodle Setup for making participants anonymous.

Once the enrolment process was complete, the study design group assignments were carried out. Each participant made two random draws from a container with the names of four surgical procedures. The first draw corresponded to procedure 'a' and the second draw to procedure 'b'. Participants were then randomly assigned to two groups (Groups A and B) according to their position in the enrolment order (1 – n^{th} position). Group A consisted of odd-number positions (1, 3, 5, 7), and Group B had even-number positions (2, 4, 6, 8). The participants completed the demographics, computer proficiency and need assessment surveys at enrolment.

The commencement date for comparing the two teaching interventions was then scheduled. The grouping functionality on Moodle was used to allow each participant to have access to the two procedures ('a' and 'b') they randomly selected. The two procedures were also sequenced using Moodle's access functionality by building conditional statements such that procedure 'b' only became accessible after completion of the retention test for procedure 'a'. Participants were told to access instructions under the traditional teaching method link on Moodle for the traditional teaching method. The following sequencing was also explained to them:

Only the pretest of procedure 'a' would be available at the beginning; after participants completed the pre-test, then the teaching intervention would be available. Upon completing the teaching intervention then, the post-test would become available. Two weeks after completing the post-test, the retention test would become accessible. The satisfaction level and procedure clarity surveys became accessible after the submission of the retention test.

This, then, was the online sequencing of the evaluation process.

The researcher kept in touch with participants and reminded them of their scheduled dates. If there were any participants who needed to postpone, the researcher would reschedule at the participants' convenience.

Upon completion, the assessment section on Moodle became inaccessible, and a new section appeared where participants could view and use the digital teaching method for the four procedures.

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The LMS grading system captured all the activities and results in its backend database.

2.4 Statistical analysis

Categorical data collected during the design phase was analysed using frequency bar charts and frequency tables. The mean was used to describe the central tendency of the differenced scores. During Phase II, the evaluation stage, the mean difference of the differenced scores for periods 1 and 2 were computed, and the significance of this difference was assessed using a dependent T-test, and the significance level was set at a p-value of 0.05. Frequency bar charts and frequency tables were used to describe the differences in satisfaction and clarity levels. The median and interquartile range were used to describe the central tendency of satisfaction and clarity level. IBM® SPSS® Statistics 25 software was used to do the statistical analysis, which was validated by a biostatistician. See attached the statistician's support letter under Appendix 2.7.

Procedure by period interaction (Carry-over effect) was no longer an issue in this case because different surgical procedures were taught at period 1 and period 2: *However, the analysis of interaction, if it happened to exist, is as follows:*

The interaction between period and procedure was investigated by using summed observations from the two groups. We can define y_{A1} as the observation from group A in period 1 and y_{B1} as the observation from group B in period 1. Let $t_A=y_{A1}+y_{A2}$ be the total of the observations from group A at the two time periods, and likewise t_B for group B. The means of the two observations for the two groups will be denoted by $\bar{t}_A$ and $\bar{t}_B$. This is shown in Table 2.3.

Table 2.3 Difference between pre- and post-test scores for both teaching methods

Group A: (a-b)				Group B: (b-a)			
Student	**Period 1**	**Period 2**	**Sum**	**Student**	**Period 1**	**Period 2**	**Sum**
1	Y_{A11}	Y_{A12}	$Y_{A11}+Y_{A12}$	1	Y_{B11}	Y_{B12}	$Y_{B11}+Y_{B12}$
2	Y_{A21}	Y_{A22}	$Y_{A11}+Y_{A12}$	2	Y_{B21}	Y_{B22}	$Y_{B21}+Y_{B22}$
:	:	:	:	:	:	:	:
12	Y_{A121}	Y_{A122}	$Y_{A11}+Y_{A12}$	12	Y_{B121}	Y_{B122}	$Y_{B121}+Y_{B122}$
Total			t_A	**Total**			t_B
Mean			$\bar{t}_A$				$\bar{t}_B$

The assumption is that in the absence of interaction of treatments over time, then the two means should be equal. It is essential to assume that data observations follow a normal distribution.

H_0: $\bar{t}_A = \bar{t}_B$

H_1: $\bar{t}_A \neq \bar{t}_B$

Since there are two samples involved, the joint variance of the two needs to be pooled, hence the statistic is used to pool.

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$$S_p(t)^2 = \frac{(n_A - 1)s(t)_A^2 + (n_B - 1)s(t)_B^2}{n_A + n_B - 2}$$

The test statistic that is to be compared to the t value with n_A+n_B-2 degrees of freedom at a pre-specified significance level is denoted by.

$$t = \frac{\bar{t}_A - \bar{t}_B}{\sqrt{S_p(t)^2\left[\frac{1}{n_A} + \frac{1}{n_B}\right]}}$$

Procedure difference: Having ascertained that there is no interaction, the next step is to use a safer method which was not affected by period difference by using the two-sample t-test to compare the means of the differences in Procedure A and in Procedure B differenced scores. This method eliminated the period effect as follows: Define y_{A1} as the observation from group A in period 1 and y_{B1} as the observation from group B in period 1. Let $d_A = y_{A1} – y_{A2}$ be the difference between first and second period differenced scores for participants in group A, while d_B is the one for group B. Thus $\bar{d}_A$ and $\bar{d}_B$ are the mean differences for groups A and B, respectively, and we expect to be equal if there is no procedure effect. It is important to understand that $\bar{d}_A$ estimates the true population mean procedure difference, $\mu_1 - \mu_2$.

Ho: $\bar{d}_A = \bar{d}_B$

Ha: $\bar{d}_A \neq \bar{d}_B$

Differencing the observations over a period eliminates the issue of period effect, which should be absent if we want to check for procedure effect. A two-sample statistic denoted by the following has a t-distribution that can be compared to the t-value.

$$t = \frac{\bar{d}_A - \bar{d}_B}{\sqrt{s_p(d)^2\left[\frac{1}{n_A} + \frac{1}{n_B}\right]}}$$

where $S_p(d)^2$ is the pooled estimate of variance.

$$s(d)_p^2 = \frac{(n_A - 1)s(d)_A^2 + (n_B - 1)s(d)_B^2}{n_A + n_B - 2}$$

Period difference: This test can be done even if the procedure effect turns out to be significant because the two may occur together but not interactively. This is done by checking the d_A against the negative value of d_B as used in testing for procedure effect.

2.5 Ethical considerations

This study was conducted in conformity with the Helsinki Declaration of ethical principles for medical research involving human participants[101]. A discussion of these ethical principles is presented in the context of this study.

Respect for persons

This is the first principle of the Belmont report, which seeks to protect the rights of all research participants[102]. Respect for persons incorporates two ethical convictions. Individuals should be treated as autonomous agents, and persons with diminished

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autonomy are entitled to protection. An autonomous person is one with the capability to deliberate about personal goals and act under the direction of such deliberation[101, 103]. The researcher acknowledged and observed this moral requirement. Special attention was paid to participants at the University of Botswana, where the researcher was the Head of the Department. The need to avoid undue pressure on a trainee who may feel obliged to favourably assess the digital teaching method as a way of appeasing the researcher was noted. This was addressed at two levels. First, during the study introduction it was emphasised that there is no particular outcome of the study which would favour the researcher. It was made clear to participants that the researcher has no conflict of interest in the success or performance of the digital teaching method. Secondly, a research assistant was engaged to enrol and register the participants to the LMS. All participants were anonymised at registration, and they were made aware of it.

Risks, burdens and benefits
Two general rules have been formulated as complementary expressions of beneficent actions. These are 'do no harm' and 'maximize possible benefits and minimize possible harms'[101, 102]. The study's benefits should outweigh the study's risks and burden on the research participants. Efforts should be made to mitigate any burden or risk that the study participants may be exposed to.

This was a low-risk study. There were six participation events for each participant spread over a month. This amount of engagement was considered a potential source of distress for the participants. To minimize the distress, the researcher adopted a more flexible participation schedule that was convenient for the participants. Participation scheduling was discussed and agreed upon with each participant. Participants were also made aware that they could reschedule if new time constraints arose. The research was conducted online, allowing the participants to choose a convenient time. The researcher remained vigilant to ensure that the well-being of participants was secure while maintaining the quality of the data collection process.
The study had an educational benefit because the content taught during the research was part of the curriculum. To maximise the benefit, a provision was made for non-participants to request and be granted access to educational videos. They were granted access at the end of the study and were also assigned a non-participant account to avoid contamination of the study results. All educational videos were made accessible to participants at the end of the study period. Presumed long-term benefits of the study included improving surgical training and surgical care outcomes.

Vulnerability of participants
Some groups and individuals are particularly vulnerable[101]. These groups have an increased likelihood of being harmed or wronged. Such groups should receive specifically considered protection. Participants in this study did not fall into any of the vulnerable groups. However, the researcher actively considered the participants' vulnerability during the study.

Research Ethics Committees
Ethical approval was obtained from the Research Ethics Committees, the Faculty of Health Sciences and the University of Pretoria (Ref: 629/2020), the University of

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Botswana (Ref:UBR/RES/IRB/BIO/GRAD/114) and the Ministry of Health Botswana (Ref: HPDME 13/18/1). All amendments to the study were submitted, reviewed and approved by the research ethics committees (Ref: 629/2020 – Line 2; 629/2020 – Line 3).

Informed Consent

Respect for persons requires that, to the degree that they are capable, participants be given the opportunity to choose what shall or shall not happen to them. Standards that need to be satisfied for informed consent to be made include the provision of sufficient information about the study[103]. The information should be comprehensible, and the agreement to participate should be done voluntarily and freely without coercion and undue influence[102, 103].

The study was introduced to potential candidates, and a study information pamphlet was given to them to read and understand the study before deciding to participate. Specifically, participants were clearly informed on study aims, methods, anticipated benefits, and potential distress that may result from participation. The researcher's telephone number and email address were provided in the pamphlet for the candidates to contact them when clarification is required. Participants were enrolled after they had freely and voluntarily expressed their interest in participating by contacting the researcher by telephone or email. Upon expressing interest in participating, participants were given login credentials to access and complete the online consent form. It was made clear to the participants that should they wish to withdraw from the study for whatever reason, they were free to do so without being victimised. Participants were informed that they would have access to the study results as they would be presented at conferences and published in peer-reviewed journals.

Privacy and Confidentiality

Precautions were taken to protect the privacy of participants and the confidentiality of their personal information[101, 103]. After enrolment, participants were anonymised in the LMS. This was achieved through a setting on the LMS Setup to make participants anonymous.

This brings the material and methods chapter to a conclusion. The study design and procedure detailed how the study objectives were met. The statistical analysis and tools used for results analysis were elaborated and justified. The chapter concluded by discussing ethical considerations. The next chapter presents the results of the study. The results of each study phase (I and II) will be presented individually with their discussion and concluding statements.

Chapter 3. Results and their discussion

The results of this study will be presented sequentially, with Phase I results and their discussion presented first, followed by Phase II results and their discussion. Phase I results focus on the design of the educational video using the ADDIE model, while Phase II results report on the comparison of the traditional teaching method and the digital teaching methods. The hypothesis of this study was specifically tested during phase II of the study. The results presented in phase II sought to prove whether or not the surgical trainees trained using the digital teaching method performed better than those taught using the traditional teaching method with respect to knowledge

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gain, knowledge retention, and self-scored satisfaction level. Furthermore, their impression regarding the clarity of the two teaching methods was assessed.

3.1 Phase I: The instruction design

The design of the digital teaching method for surgical procedure cognitive skills was constructed using the ADDIE model of instructional design. It took six months to complete the design of the digital teaching method, an educational video with embedded assessment. Educational videos for four surgical procedures were produced. The four surgical procedures were: Open appendicectomy (OA), Mastectomy and axillary node clearance (Mx & ANC), Inguinal hernia repair (IHR) and Below knee amputation (BKA). Snapshots of the four completed educational videos with a series of thumbnails at the bottom are shown in Figures 3.1-3.4.

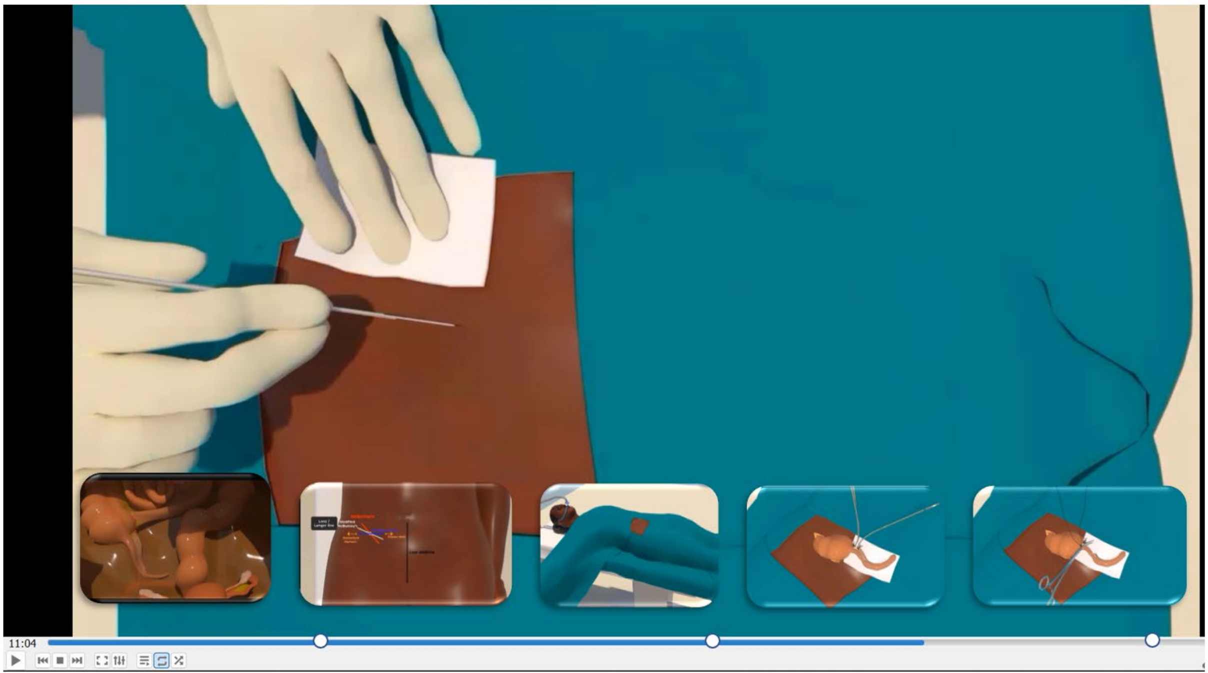

Figure 3.16 Snapshot of the open appendicectomy educational video.

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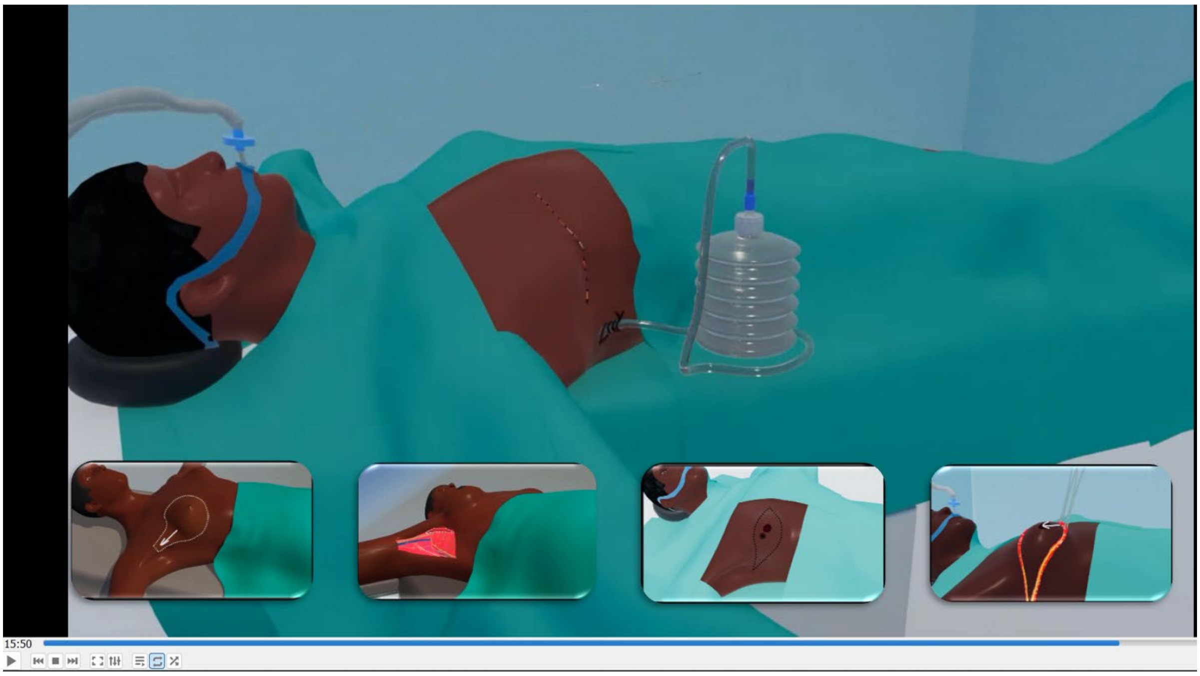

Figure 3.17 Snapshot of the Mastectomy and axillary clearance educational video.

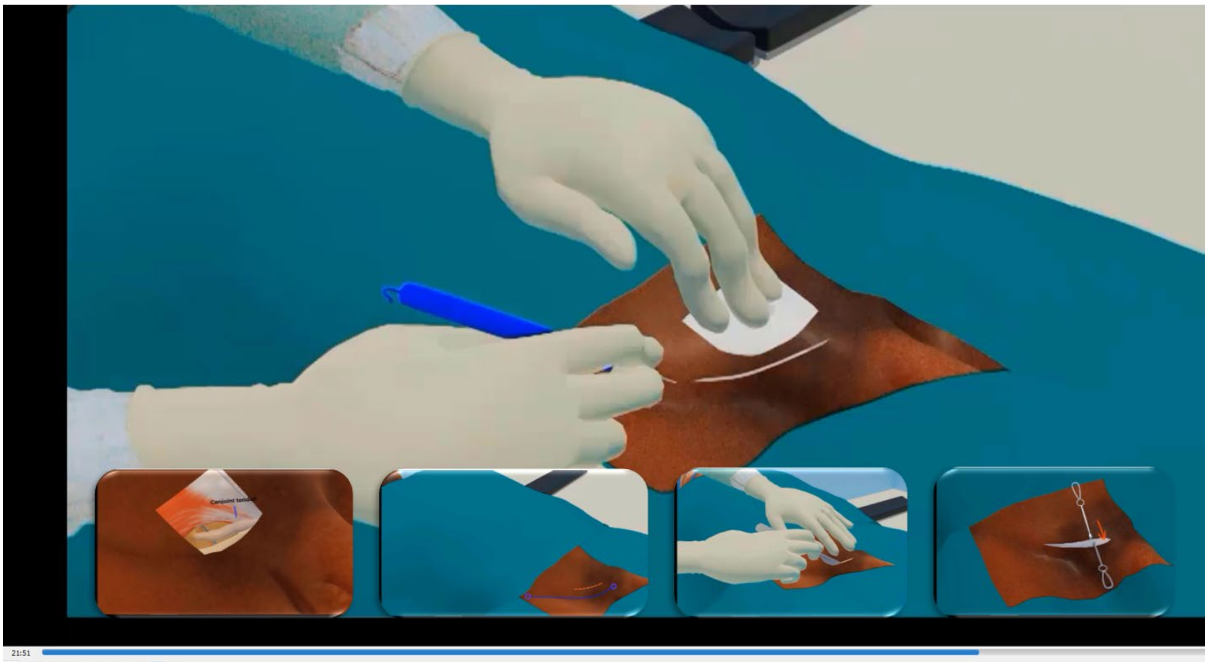

Figure 3.18 Snapshot of the Inguinal hernia repair educational video.

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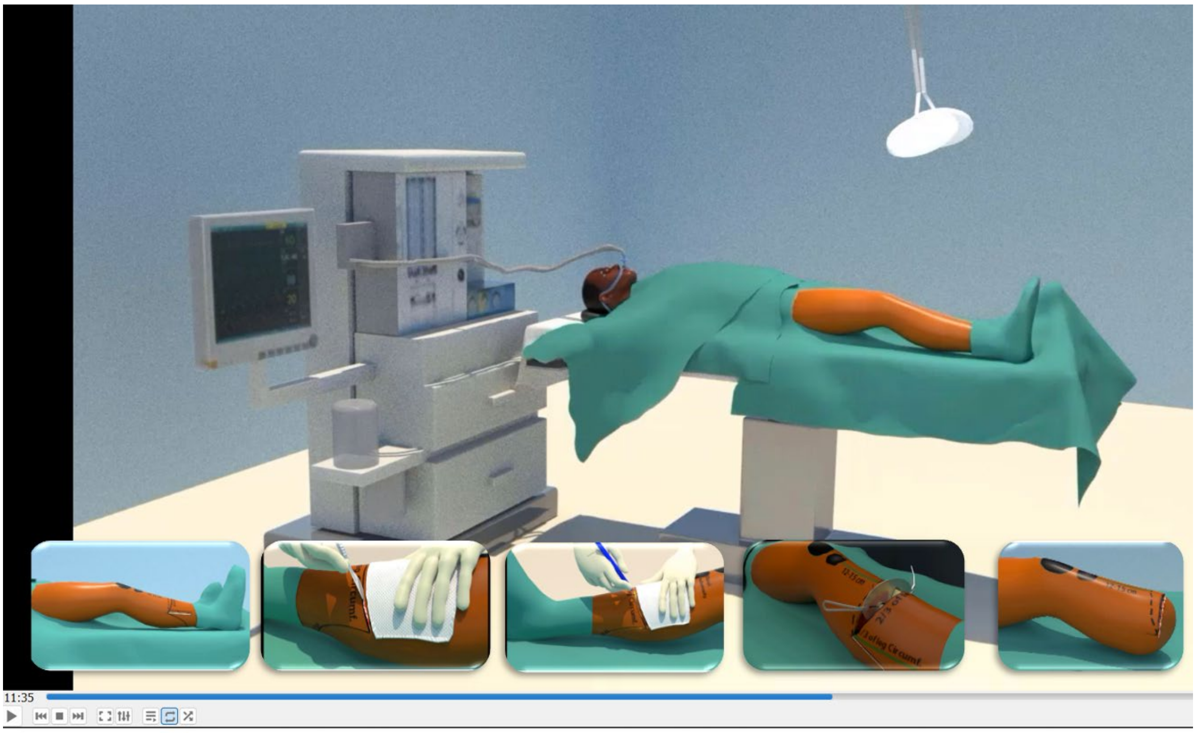

Figure 3.19 Snapshot of the Below knee amputation educational video.

3.1.1 Embedded assessment for learning

Each educational video had at least three embedded assessment events. The assessment events are shown in Figure 3.5 along the timeline of the video as assessment events 1, 2, and 3. As the play head of the timeline reaches the assessment event, a pop-up message (1) would appear, allowing the participant to replay the last section of the video or take the embedded assessment. An example of an MCQ question is shown (2), and a wrong attempt with triggered instant feedback is also shown (3). After answering all the questions, a score summary is shown with the option to view all answers again or continue viewing the subsequent section of the video. If the participant had scored less than 75%, the 'continue' button would be 'replay last section', and the process would start again.

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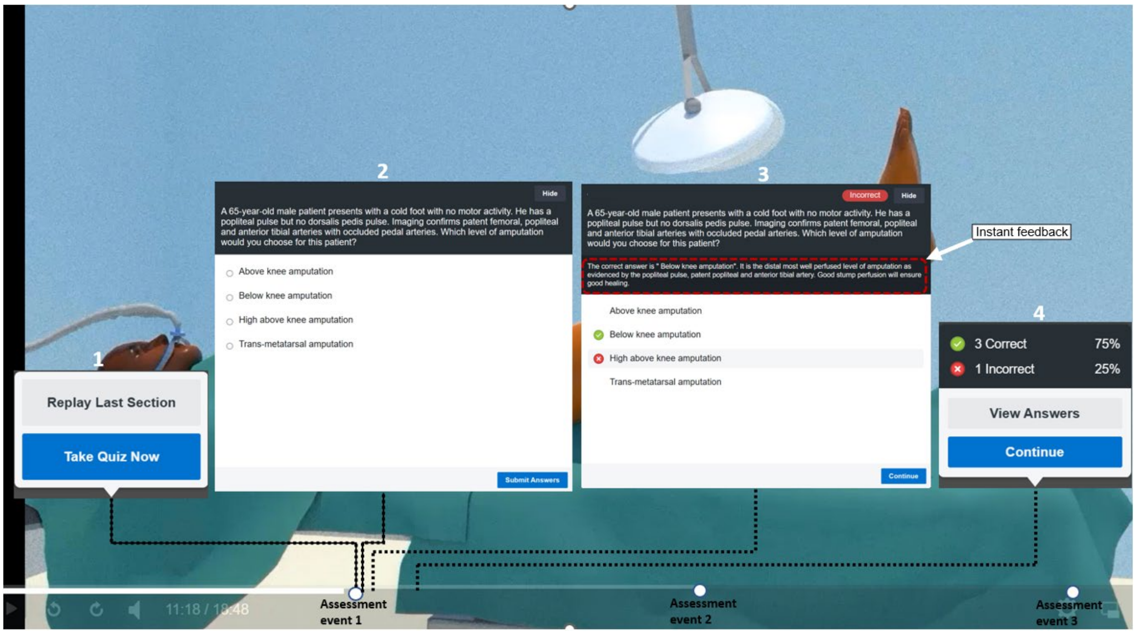

Figure 3.20 Interactive options of the video-embedded assessment.

Each educational video was reviewed by the Supervisors and members of the Department of Surgery four times before approval. The review meetings with the Supervisors were both physical and virtual. Review materials were submitted to Supervisors mostly via Google Drive. The following software programmes were used during the production process: Autodesk® Maya 2020, Autodesk® 3DS max™ 2020, Zbrush™ 2020, Adobe® Creative Cloud software, especially Photoshop™ 2020, Premier Pro™ 2020, After Effects™ 2020, Media Encoder™ 2020, Audition™ 2020 and Captivate™ 2020. Due to the complexity of the work, the researcher had to buy and learn new software, and these were Handbrake 1.3.3 and Camtasia®. Handbrake 1.3.3 was easy to learn. However, learning to use Camtasia® involved a steep learning curve.

The final educational videos were uploaded into the LMS during the evaluation stage (Phase II).

3.1.2 Discussion of Phase I results

Phase I designed the digital teaching method for surgical procedure cognitive skills using 3D animation videos and embedded continuous assessments. There is ample evidence in the literature arguing that surgical procedure cognitive skills are not well covered in the traditional teaching model [22, 24, 25, 27, 28, 42]. Yet, surgical procedure cognitive skills are essential for critical decision-making by a surgeon and are a core competency necessary for positive outcomes in surgery[67, 68]. In response, this study designed a digital teaching method for surgical procedure cognitive skills using the ADDIE model of instructional design. The product of this design was four educational videos with embedded assessments created using the 3D animation production pipeline.

A needs analysis yielded a unanimous confirmation that there is a need for structured cognitive skills training before observing or performing a surgical

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procedure. This needs assessment survey was conducted during the analysis stage of the ADDIE model. Gallagher and colleagues [104] recommended a similar method in which cognitive skills were trained before attempting technical skills in the operation room. Grantcharov suggested a systematic approach that included introductory topics (surgical anatomy, indications, preoperative work-up, etc.), and an illustration of the surgical procedure steps was proposed[42]. The trainees unanimously endorsed the proposal during the needs assessment survey. These results suggest that novice surgical trainees are aware of the deficiency in the traditional teaching method. In 2019, Raîche et al. explored the challenges junior residents faced from a cognitive standpoint when the traditional method of observing surgery was used to teach surgical techniques. He found that trainees raised similar concerns regarding their struggle to understand what happens during a surgical procedure in the operating room[28].

While some content development was relatively simple, some of it, especially 3D animation video production, required advanced technical skills and more resources[105]. Eleven applications were used during the complete 3D animation video production pipeline. Following an established production process was key, and being systematic during the production process was equally important[106]. Best practices included setting up a good file and folder naming system and appropriately setting software units and working environments. Preventive measures such as turning on software autosave functionality and incrementally saving work avoided losing valuable work during a software crash. The 3D animation production pipeline is time-consuming, but best practices and systematic work produced satisfying results. The researcher particularly found it important to set up the work environment appropriately before starting the 3D animation process. Finally, appropriately allocating hardware to tasks takes production to another level. The researcher had two high-performance computers [Intel(R) Core(TM) i7-9700 CPU @ 3.00GHz 3.00 GHz, Ram(32.0 GB), 64-bit operating system] allocated to the production pipeline. One for the pre-production and production processes and another for the postproduction process, which included rendering. Rendering is a highly computer-intensive job[107]. A render may take 24 hours to complete.

The instructional design was completed but came with several challenges worth reflecting on. The difficulties encountered are outlined below, and how the researcher addressed them is also given.

i. The researcher required video editing software capable of incorporating quizzes within the educational videos and also generating instant feedback when the questions were attempted. The software needed the functionality to prevent the participant from skipping answering assessment events embedded into the video. The participant needed to complete the embedded assessments and score above 50% for them to be able to proceed with watching the rest of the video. The researcher chose Camtasia® software after doing extensive research and consulting. However, the researcher also had to learn how to use the software, so he did through tutorials on YouTube. It was a time-consuming steep learning curve.

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ii. The final video files tended to be larger in size, about 1 GB, making uploading and sharing the video on LMS impractical. After searching online, the researcher discovered a software called Handbrake 1.3.3 , an open-source video transcoder. It reduced the size of the video by up to 80% of the original size with minimal loss of video quality.

iii. During the production process, especially for the 3D animation videos, applications would crash, and files would be lost or corrupted. This was especially the case during sculpting, 3D modelling, texturing and rendering. Incrementally and frequently saving work reduced the risk of losing all the researcher's hard-earned work. The researcher also activated the software's autosave functionality and increased the autosaving frequency. These two interventions ensured that there was always a recently saved file to start from without starting all over again.

The complete production of the four educational videos took four months. However, the researcher noted that subsequent work took a shorter period as more skills and experience were gained.

To conclude the instructional design phase, four educational videos with embedded continuous assessments were designed following the ADDIE instructional design model and using the 3D animation pipeline. The educational videos were used as the digital teaching method for surgical procedure cognitive skills during Phase II of the study. The digital teaching method was compared to the traditional teaching methods. The results of this comparison and their discussion are presented next.

3.2 Phase II: The evaluation stage

The evaluation stage compared the digital teaching method to the traditional teaching method for surgical procedure cognitive skills. The compared variables were knowledge gain, satisfaction level and procedure clarity. The knowledge gain was assessed using pre-, post-, and retention tests, while the satisfaction level and the procedure clarity were compared using survey questionnaires on a 5-point Likert scale. The above comparison tested the null and alternative hypothesis of this study. Participants' baseline information regarding demographics, computer proficiency and needs assessment was collected using survey questionnaires. First is the presentation of the results of an LMS layout design designed to conform with the study design. The layout design was to allow complete online administration of the study.

3.2.1 The study design and course layout design

The evaluation of the two teaching methods was conducted on the LMS.
The LMS layout design on which the study was run factored in the study design (crossover-repeated measures) using the LMS functionalities. These LMS functionalities made it possible to sequence and control access to the study content in an adaptive release fashion, enabling it to be run entirely online. Figure 3.6 shows the completed online LMS course layout with uploaded content. A video

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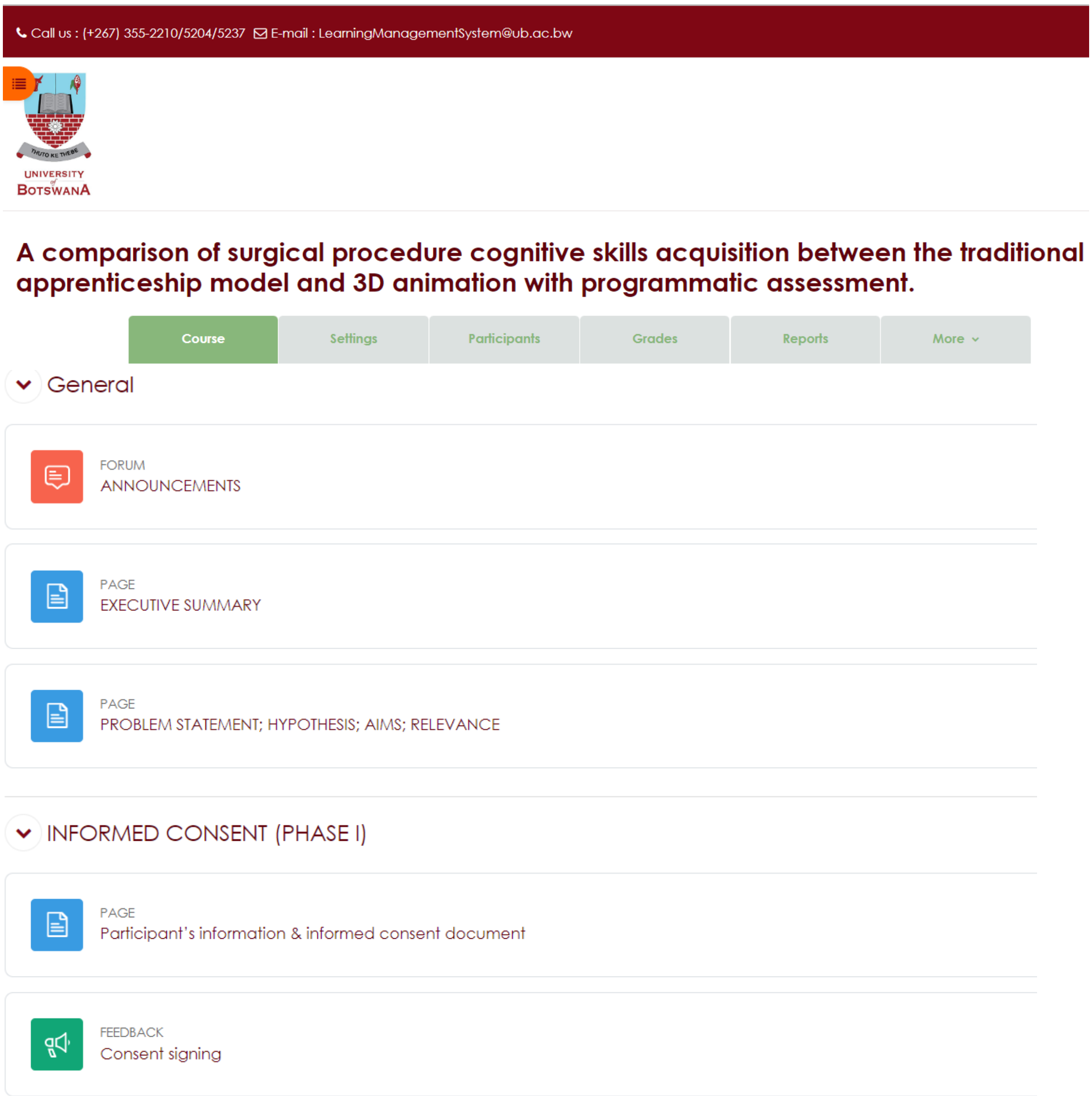
demonstration of the layout design and its functionalities is provided at this link. https://youtu.be/X_HhXBp15RU.



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Computer Experience Questionnaire

FEEDBACK
Computer Experience Questionnaire

Demographics Questionnaire

FEEDBACK
Demographics

Needs Assessment Questionnaire

FEEDBACK
Learner Needs Assessment for a surgical procedure cognitive skills training

Open appendicectomy (OA)

Not available unless any of:
- You belong to **a1**
- You belong to **b1**

QUIZ
Pretest - Open appendicectomy

Not available unless any of:
- You belong to **a1**
- You belong to **b1**

SCORM PACKAGE
Open appendicectomy (New teaching approach)

Not available unless:
- The activity **Pretest - Open appendicectomy** is marked complete
- You belong to **A**

PAGE
Open appendicectomy (Traditional teaching approach)

Not available unless:
- The activity **Pretest - Open appendicectomy** is marked complete
- You belong to **T**

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QUIZ
Posttest - Open appendicectomy

Not available unless any of:
- The activity **Open appendicectomy (New teaching approach)** is marked complete
- The activity **Open appendicectomy (Traditional teaching approach)** is marked complete

QUIZ
Retention test - Open appendicectomy

Mastectomy and axillary node clearance

Not available unless any of:
- You belong to **a2**
- You belong to **b2**

QUIZ
Pretest - Mx ANC

Not available unless any of:
- You belong to **a2**
- You belong to **b2**
- The activity **Learner Needs Assessment for a surgical procedure cognitive skills training** is marked complete

SCORM PACKAGE
Mastectomy and axillary node clearance (New teaching approach)

Not available unless:
- The activity **Pretest - Mx ANC** is marked complete
- You belong to **A**

PAGE
Mastectomy and axillary node clearance (Traditional teaching approach)

Not available unless:
- The activity **Pretest - Mx ANC** is marked complete
- You belong to **T**

QUIZ
Posttest - Mx ANC

Not available unless any of:
- The activity **Mastectomy and axillary node clearance (New teaching approach)** is marked complete
- The activity **Mastectomy and axillary node clearance (Traditional teaching approach)** is marked complete

QUIZ
Retention test - Mx ANC

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Inguinal hernia repair

Not available unless any of:
- You belong to **a3**
- You belong to **b3**

QUIZ
Pretest - Inguinal hernia repair

Not available unless any of:
- You belong to **a3**
- You belong to **b3**

SCORM PACKAGE
Inguinal hernia repair (New teaching approach)

PAGE
Inguinal hernia repair (Traditional teaching approach)

Not available unless:
- The activity **Pretest - Inguinal hernia repair** is marked complete
- You belong to **T**

QUIZ
Posttest - Inguinal hernia repair

Not available unless any of:
- The activity **Inguinal hernia repair (New teaching approach)** is marked complete
- The activity **Inguinal hernia repair (Traditional teaching approach)** is marked complete

QUIZ
Retention test - Inguinal hernia repair

Below knee amputation

Not available unless any of:
- You belong to **a4**
- You belong to **b4**

QUIZ
Pretest - BKA

Not available unless any of:
- You belong to **a4**
- You belong to **b4**

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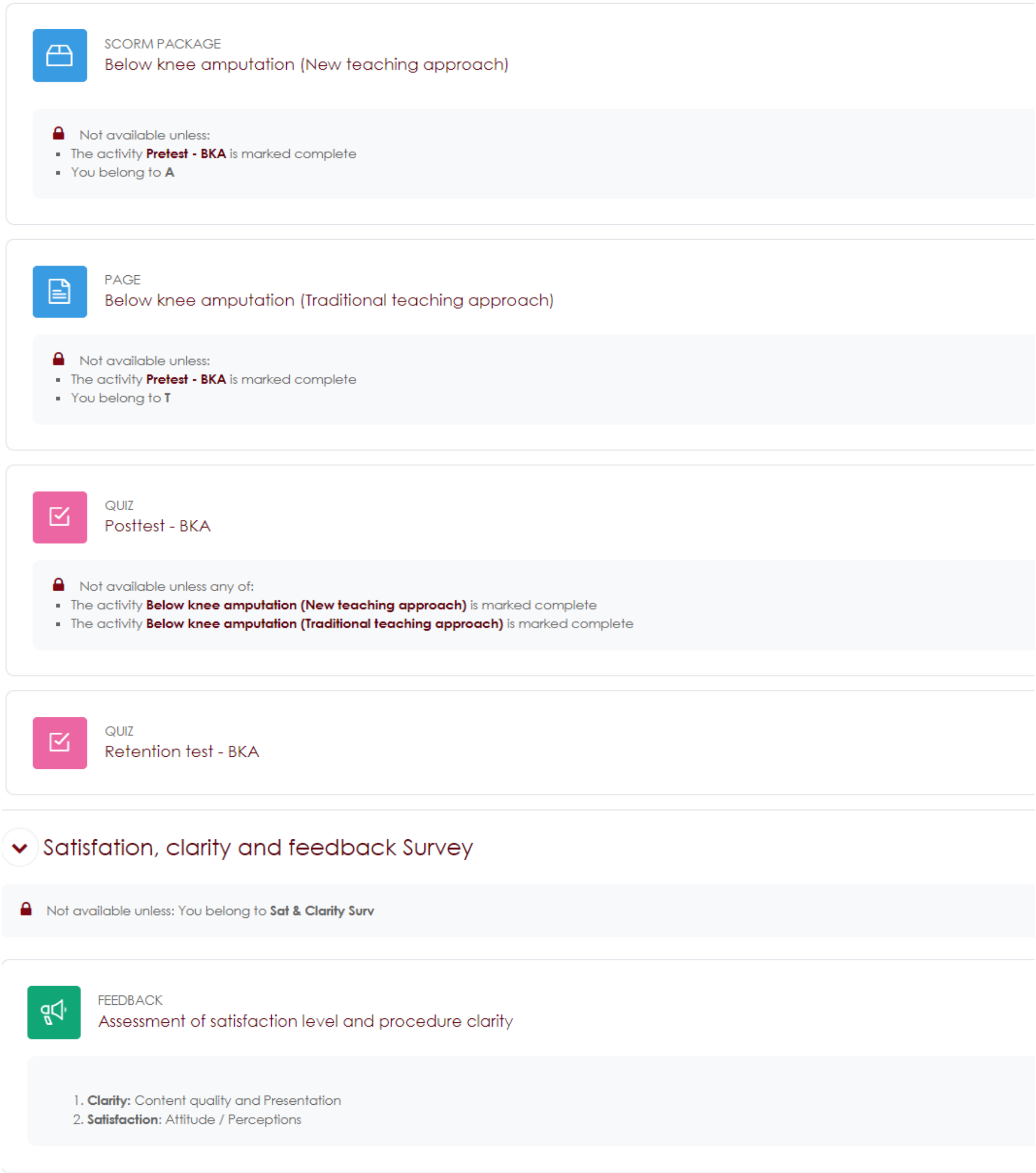

Figure 3.21 Snapshot of the complete Moodle course.

The designed digital teaching method was compared to the traditional teaching method during Phase II (Evaluation) of the study, and the results are elaborated on in the following section.

3.2.2 **Demographics**

Thirty-five participants were recruited, 31 were enrolled, and 29 completed the study. Two of the thirty-one enrolled participants fell off the study and did not complete the study. The reason for their failure to complete the study was not known. The mean age of the participants was 31.5 years (SD = 3.74). Ten were general surgery

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residents, and 19 were medical officers in the departments of surgery. There were 10 females and 19 males, which is in keeping with the general demographics of candidates in participating departments of Surgery. Participants' average time spent in the surgical departments was 1.9 years (SD =1.36).

3.2.3 Computer proficiency

The findings of a computer proficiency questionnaire were as follows:

- All participants indicated that they used a computer every day. This was a required skill because the study involved the use of computers.
- 27.6% (8/29) of participants indicated that they play computer games once a week, 18 once a month and three never.
- All participants had cell phones and laptops, 13.8% (4/29) additionally had desktops, and one had a gaming console.

Of the nine computer proficiency questionnaire items, all participants scored the highest on a Likert scale (1-5) for items 1,3,4,6,7 and 9 shown in Table 3.1. In general, the participants were computer literate, and all could easily watch movies and videos on a computer.

Table 3.4 Likert scale rating frequency for computer proficiency questionnaire.

Item	Computer proficiency questionnaire items	Likert Scale (1-5) Frequency				
		1	2	3	4	5
1	I can use a mouse	0	0	0	0	29
2	I can use a computer keyboard to type:	0	0	0	1	28
3	I can open e-mails	0	0	0	0	29
4	I can send e-mails	0	0	0	0	29
5	I can find information about local community resources on the Internet	0	0	0	3	26
6	I can find information about my hobbies and interests on the Internet	0	0	0	0	29
7	I can use a computer to watch movies and videos	0	0	0	0	29
8	I can use a computer to play games	1	1	0	13	14
9	I can use a computer to listen to music	0	0	0	0	29

The findings showed that participants had basic (daily use of a computer) and most advanced skills (computer gaming), making them proficient enough to participate in the study without limitations.

3.2.4 The learner needs assessment survey

The learner needs assessment survey was completed again during Phase II of the study. There were 29 participants during Phase II compared to 23 during Phase I. During Phase I, not all University affiliated hospitals were recruited due to distance and COVID-19 constraints.

The needs assessment revealed that all participants thought all the listed topics should be covered before a trainee assists/performs a surgical procedure. All

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participants indicated that the demonstration of surgical procedure steps should be covered in detail before assisting or performing it. Additionally, 93.1% (27/29) indicated that pre-operative preparation and post-operative management should be covered in detail. Ninety-seven percent (28/29) felt the same about postoperative complications and their management. Table 3.2 shows the results of the needs assessment survey.

Table 3.5 Needs assessment survey results.

Topics	Is it relevant to cover the topic before doing/assisting the surgical procedure in the operating room?		To what extent should the topic be covered?	
	Yes	No	Detailed	Brief
1. Introduction to the surgical procedure	29	0	6	23
2. Indications for a surgical procedure	29	0	15	14
3. Contra-indications for a surgical procedure	29	0	8	21
4. Preoperative preparation	29	0	27	2
5. Demonstration of positioning	29	0	9	20
6. Demonstration of exposure and access	29	0	12	17
7. Demonstration of operative steps	29	0	29	0
8. Demonstration of closure	29	0	7	22
9. Postoperative management	29	0	27	2
10. Complications and their management	29	0	28	1

3.2.5 The difference in knowledge gain

The differenced score was calculated as the difference between the post-test and the pre-test scores. A second score, the ‘differenced retention score’, was calculated as the difference between the retention test and the pre-test scores. The pair of the differenced scores (pair one) and the differenced retention scores (pair two) for the digital and the traditional teaching methods are shown in Figures 3.7 and 3.8, respectively. The differenced scores (pair one) measured the improvement score due to each intervention (teaching methods). The differenced retention score measured the improvement score due to retained knowledge two weeks after an intervention. It is used as a surrogate measure of how well the participants retained knowledge for two weeks due to an intervention. It estimates each teaching method's role in the participants' retention capacity.

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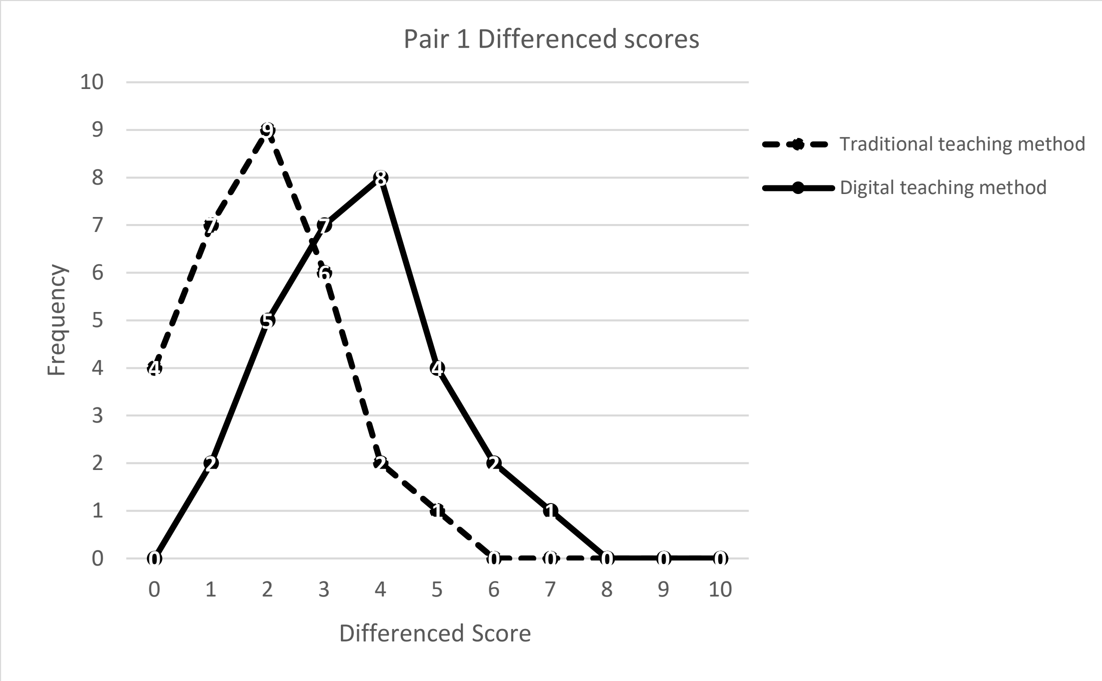

Figure 3.22 The differenced scores for the two teaching interventions

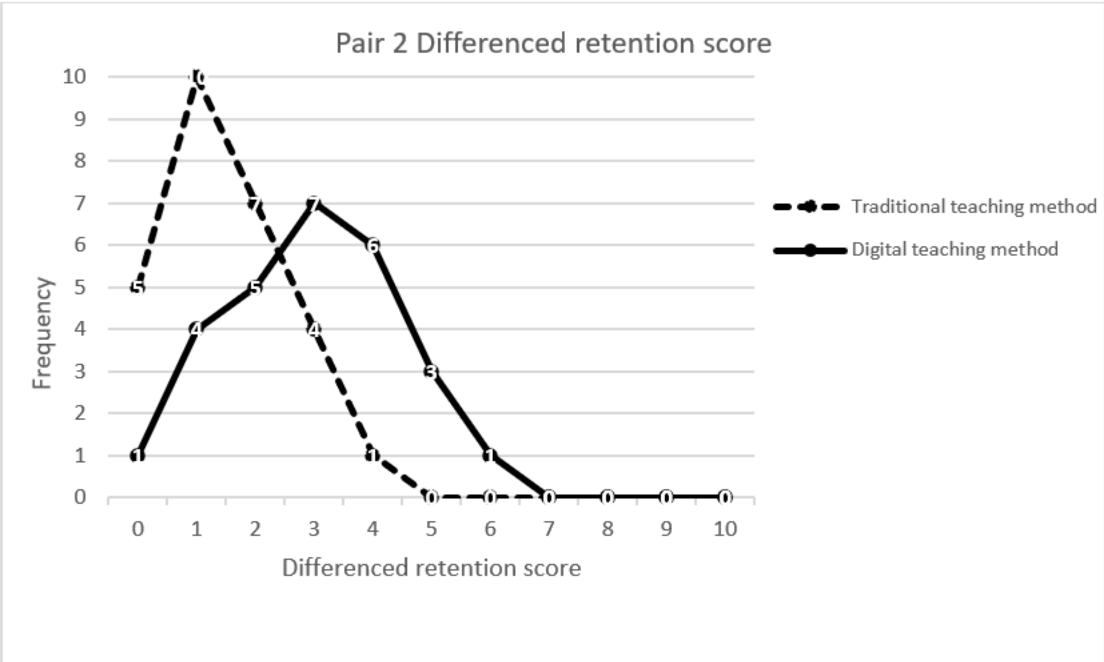

Figure 3.23 The differenced retention scores for the two teaching interventions

A paired sample T-test analysis was used to assess the significance of the difference between the mean differenced scores of the digital and the traditional teaching methods in pair one. Additionally, the significance of the difference between the mean differenced retention scores of the digital and the traditional teaching methods in pair two was also determined using the paired sample T-test.

The following assumptions were made for the paired sample T-test analysis to be valid[108]:

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1. The dependent variables must be continuous and measured at interval or ratio levels. The condition was met because scores were continuous variables.
2. The observations should be independent of one another. The condition was met because two different procedures were used during periods 1 and 2 to avoid a knowledge carryover effect.
3. The dependent variable should be approximately normally distributed.
4. The dependent variable should not contain any outliers. Figures 3.9 and 3.10 show that the differenced scores and the differenced retention score for the digital and traditional teaching methods are normally distributed with no outliers.

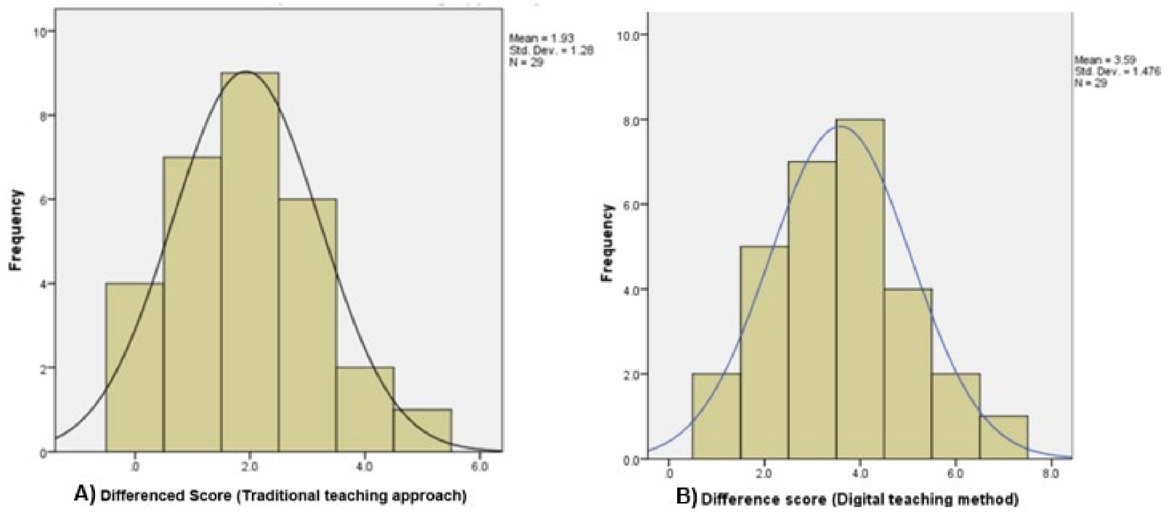

Figure 3.24 Normally distributed differenced scores for the teaching methods.

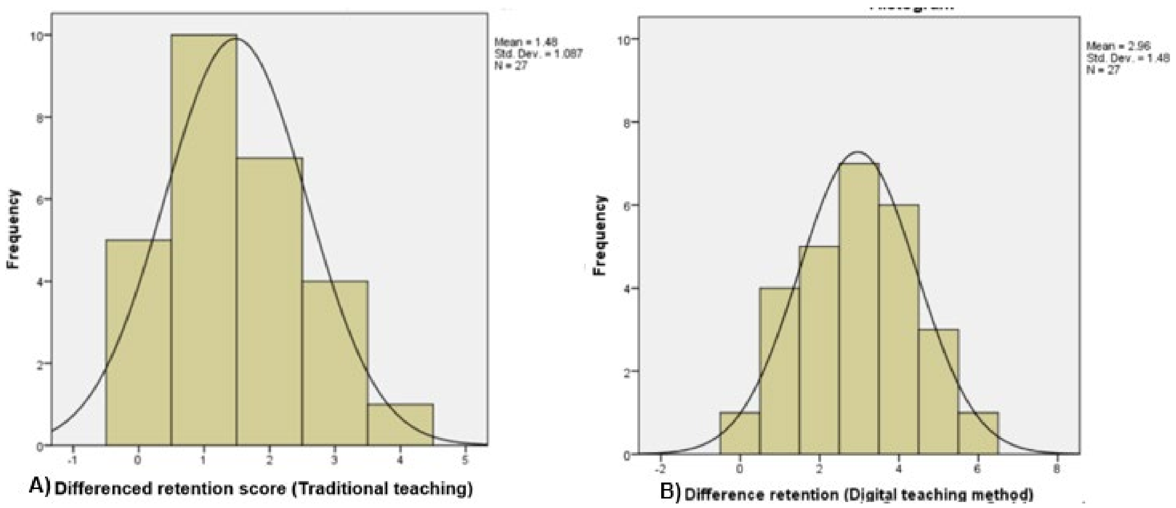

Figure 3.25 Differenced retention scores for the teaching methods.

The paired sample t-test showed that the mean differenced score for the digital teaching method (M = 3.59, SD = 1.48) was significantly greater than that of the traditional teaching method (M = 1.93, SD = 1.28), $t(28) = -10.950$, $p < 0.001$ (two-

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tailed). Likewise, the mean differenced retention score for the digital teaching method (M = 2.96, SD = 1.480) was significantly higher than that of the traditional teaching method (M = 1.48, SD = 1.087). 72% (18/25) preferred the digital teaching method over the traditional one.

Table 3.3 below shows the paired samples T-test results for pairs 1 and 2.

Table 3.6 Paired samples T-test.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper			
Pair 1	(Differenced Score of the traditional teaching method) – (Differenced score of the digital teaching method)	-1.6552	.8140	.1512	-1.9648	-1.3456	-10.950	28	p<0.001
Pair 2	(Differenced retention score of the traditional teaching method) – (Differenced retention score of the digital teaching method)	-1.481	1.252	.241	-1.977	-.986	-6.150	26	p<0.001

3.2.6 **Satisfaction level and procedure clarity assessment**

A13–-item satisfaction level and surgical procedure clarity assessment using a Likert scale rating of 1-5 was used. Table 3.4 shows the rating frequency of 25 participants for each of the 13 items of the questionnaire. All participants strongly agreed that they were satisfied with the digital teaching method, while 24 out of 25 strongly agreed that they would recommend it to a colleague and its adoption. In all the 13 questionnaire items, there was a favourable rating of the digital teaching method over the traditional one in teaching surgical procedure cognitive skills. This assessment was on level 1 of the Kirkpatrick Model. It was learner-focused and evaluated the learner's satisfaction with the efficacy of the training[109].

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Table 3.7 Rating frequencies for each item

Item No.	Satisfaction level and procedure clarity questionnaire items	Likert scale Frequency				
		1	2	3	4	5
1	There was no confusing information in the traditional teaching method	0	0	1	20	4
2	There was no confusing information in the digital teaching method (Video illustration)	0	0	0	1	24
3	Information was presented logically in the traditional teaching method	1	0	1	19	4
4	Information was presented logically in the digital teaching method (Video illustration)	0	0	1	1	23
5	The traditional teaching method helped me to better understand the topic	0	0	5	19	1
6	The digital teaching method (Video illustration) helped me to better understand the topic	0	0	0	1	24
7	I feel like the traditional teaching method helped me achieve the learning outcomes.	0	0	4	20	1
8	I feel like the digital teaching method helped me achieve the learning outcomes.	0	1	0	1	23
9	Overall, I am satisfied with the traditional teaching method.	0	1	2	21	1
10	Overall, I am satisfied with the digital teaching method (Video illustration).	0	0	0	0	25
11	I would recommend the digital teaching method (video illustration) to a colleague	0	0	0	1	24
12	I recommend the adoption of the digital teaching method (video illustration)	0	0	0	1	24
13	Assessments in the digital teaching method (Video illustration) facilitated learning.	0	0	0	2	23

3.2.7 Discussion of Phase II results

This study sought to design an alternative digital teaching method for surgical procedure cognitive skills using 3D animation videos and continuous assessment. This was in response to the suggestion by various authors that surgical procedure cognitive skills are inadequately covered by the traditional teaching method despite their significance in improving surgical outcomes[22, 24, 25, 27, 28, 42, 67, 68].
The digital teaching method was designed and evaluated by comparing it with the traditional teaching method. The complete training package was delivered to the trainees via an LMS. This study focused on the training of surgical procedure cognitive skills.

Evaluation of the teaching methods (Phase II)

The choice of Moodle as an LMS in this study was based on the researcher's experience with using the LMS from a previous study [51]. Additionally, the LMS is used by the University of Botswana. Therefore, there is available support from the University's IT department. The support rendered by the institutional Information and Technology (IT) department was particularly important in this study. The IT department manually created a new standalone course to allow the researcher to enrol non-UB participants into the course on the University's LMS without interfering with the mainstream courses.

All participants had their computer proficiency assessed, and they had the basic computer skills required to participate without being disadvantaged. These included their ability to use a mouse and keyboard, listen to music on a computer and search/navigate the internet[90]. These computer skills allowed the participants to interact with the LMS course without limitations.

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Ninety-seven percent (97%) of participants were found to have improved knowledge gained in surgical procedure cognitive skills after being taught using the digital teaching method($M = 3.59$, $SD = 1.48$) compared to the traditional one ($M = 1.93$, $SD = 1.28$), $t(28) = -10.950$, $p < 0.001$ (two-tailed). Likewise, participants were found to have greater knowledge retention after the digital teaching method compared to the traditional one: ($M = 2.96$, $SD = 1.480$) vs ($M = 1.48$, $SD = 1.087$), $t(26) = -6.150$, $p < 0.001$.
These findings suggest a better understanding and knowledge retention with the digital teaching method. These findings were more attributable to the interventions because of several factors related to the study design[110]. First, the study was well-powered, with a larger sample size than the calculated minimum sample size. By its nature, the repeated measures study design requires a relatively smaller sample size. Furthermore, the group served as its own control, minimizing the variability of the results and favouring their validity. Third, the carryover effect, a weakness of this study design, was minimised by assessing the knowledge gain for two different surgical procedures in periods 1 and 2. Another weakness of the study design that was minimised was the bias due to the treatment order. This occurs due to fatigue and the carryover effect mentioned above. To minimize the bias, half the participants started with Intervention 1, while the other half started with Intervention 2 to cross out the impact by equally distributing it between interventions. The reduction of these confounders made the findings in this study more attributable to the compared interventions. Finally, serious attrition of participants over multiple interventions can occur[110]. However, this was not the case in this study, as we started with 31 participants, and only two stopped participating. Our sample size was still more than the calculated minimum sample size. The researcher also settled for a time-lapse of no more than two weeks before the retention test was conducted, to reduce the risk of a high attrition rate.

The paired T-test evaluation results' validity required that the differenced scores be normally distributed without outliers[108]. Using the graph assessment, the variables were normally distributed. However, the Kolmogorov-Smirnova and the Shapiro-Wilk showed that all were indeed normally distributed. There were no outliers. Our study findings were similar to other studies as regards better knowledge gain with digital teaching methods, compared to traditional teaching methods [51]. Therefore, the new digital teaching method is a viable alternative to teaching cognitive surgical procedure skills.

Out of the 29 participants, only 25 completed the satisfaction level and procedure clarity assessment survey. The reduced number of participants who completed the survey may be a sign of study fatigue. Generally, the participants were more satisfied with the digital teaching method than the traditional teaching method regarding teaching surgical procedure cognitive skills. The digital teaching method was rated 5 by all participants, while 84% (21/25) rated the traditional teaching method 4 on a 5-point Likert scale. They also considered the digital teaching method clearer than the traditional one, with 92% (23/25) of the participants rating it 5 and 80% (20/25) rating the traditional teaching method 4 on a 5-point Likert scale. Previous studies have produced similar findings[51-53]. However, this study did not seek to discover why participants had such high satisfaction levels and ratings for the clarity of the teaching method. A shorter learning duration has been shown to be

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one of the desirable factors of digital teaching methods[51, 53, 54]. Further studies are needed to define factors that make digital education more effective.

All things considered, the findings are suggestive that the digital teaching method is more effective than the traditional teaching method in teaching surgical procedure cognitive skills. It is consistent in quality, in the message delivered and in the content. Therefore, it remains a viable alternative for teaching surgical procedure cognitive skills.

To conclude the results of the evaluation stage, the digital teaching method yielded better knowledge gain and retention than the traditional teaching method in teaching surgical procedure cognitive skills. Furthermore, participants were more satisfied with the digital teaching method and found it clearer than the traditional teaching method. Hence the alternative hypothesis of the study was proven to be true. It stated that: Trainees taught surgical procedure cognitive skills using the digital teaching method would perform better than those taught using the traditional teaching method in terms of knowledge gain, knowledge retention and self-reported satisfaction level. Furthermore, trainees would consider the teaching clarity of the digital teaching method to be better than that of the traditional method.

This study presents two viable benefits to adult learning; structured teaching and online content delivery. The systematic scaffolded classifications of cognitive learning processes in Bloom's taxonomy provide educators with a framework for developing learners towards functioning at higher thinking levels[34]. Nurturing critical thinking during training is essential to ensure quality surgical care and better outcomes. In the twenty-first century and the era of self-directed learning, content accessibility and ease of understanding are crucial[111]. Convenience in the form of being in control of when and at what pace to learn are motivators in adult learning. Multimodal content delivery provides opportunities to present multiple representations of content (text, video, audio, images, interactive elements) to cater for a diverse student body. Multimodal content delivery ensures an inclusive learning environment[112]. Content delivery through LMSs is convenient to a surgical trainee who has to contend with a busy clinical schedule during training[24]. Digital teaching methods, when appropriately used, therefore, provide opportunities for fostering effective adult and self-directed learning. Online content delivery further opens opportunities for regional and local collaborations. Furthermore, curricular unification and standardization through joint platform usage is possible and could be beneficial in resource limited settings.

Chapter 3 presented the results of this study, starting with Phase I, which designed the digital teaching method for surgical procedure cognitive skills. The ADDIE model of instructional design guided the design process. The digital teaching method was an educational video with embedded continuous assessments with instant feedback. Challenges experienced during the design process and their solutions were outlined. Phase I results were then discussed. Finally, the efficacy of the educational video in teaching surgical procedure cognitive skills was compared to that of the traditional teaching method during Phase II of the study. The LMS course layout design for conducting the evaluation was presented. Knowledge gain, teaching method clarity and participants' satisfaction level were assessed. This was followed by the discussion of the findings. The next chapter will draw conclusions from this chapter,

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contextualise them to the study limitations, present recommendations, outline take-home messages and list dissemination outlets used to share the study results. A list of future research topics are also suggested.

Chapter 4. Conclusion, limitation and recommendations

In the previous chapter, Phase I results on the design of the digital teaching method for surgical procedure cognitive skills were presented and discussed. An educational video with embedded continuous assessments was designed using a 3D animation pipeline. In the same chapter, Phase II results were presented and discussed, comparing the digital and traditional teaching methods. This chapter summarises how the study aims, and objectives were achieved, states study limitations and presents study recommendations and take-home messages.

This study was conducted in response to the emerging evidence highlighting the inadequacy of the traditional teaching method of the apprenticeship model in teaching surgical procedure cognitive skills. It set out to design a digital teaching method for surgical procedure cognitive skills using 3D animation videos and continuous assessment. The efficacy of the digital teaching method was assessed by comparing it to the traditional teaching method. The study findings were as follows:

Students taught surgical procedure cognitive skills using the digital teaching method had better knowledge gain and retention when compared to those taught using the traditional teaching method. In addition, participants were more satisfied with the digital teaching method than the traditional one in teaching surgical procedure cognitive skills. Additionally, they considered the digital teaching method clearer than the traditional one. Ninety-two percent (92%) rated the logical presentation of content in the digital teaching method highly, compared to 16% for the traditional method.

Furthermore, 96% (24/25) gave the digital teaching method the highest rating for helping them better understand the subject, compared to 4% (1/25) for the traditional teaching method. On recommending the procedure to a colleague and for adoption as a teaching method for surgical cognitive skills, 96% (24/25) rated these recommendations the highest.

The researcher acknowledges the following limitations of the study:

- The participants were alone when attempting the tests online and could easily have been cheating. There is no reason, however, to believe that they would particularly do so in favour of one teaching method.
- There were more medical officers than surgical registrars. However, the measured determinant of knowledge gain is not reflective of previous knowledge but the difference between initial knowledge and knowledge gain attributable to the intervention. Therefore, the difference between the pre-test and post-test scores, the differenced score in this study, was used to measure knowledge gain. The assumption is that the effect of a participant's position and pre-existing knowledge is minimal.

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- There is a potential that candidates did read before attempting the retention test, therefore, scoring higher on the retention test. However, this possibility was true for both interventions; thus, the effect would have crossed out.
- This was a small-scale study, and despite it having a sample size greater than the calculated minimum sample size, larger-scale studies are recommended to provide greater statistical power to the findings. The inclusion of more universities is recommended.
- Due to time constraints imposed by study duration, more time was spent in designing the educational video leaving limited time to evaluate the effectiveness of the digital teaching method. This led to the allocation of a shorter time interval before measuring knowledge retention. A longer time interval could be more representative of long-term knowledge retention from the digital teaching method. Therefore, a longer study period is recommended in subsequent similar studies.

The researcher recommends adopting the digital teaching method for teaching surgical procedure cognitive skills to produce surgeons competent in decision-making. Adapting surgical training curricula by incoperating the teaching of surgical procedure cognitive skills in a reproducible, systematic and sequential way will enhance the quality of surgical education. This would further translate into improved patient operative outcomes. Curricular developers, programme directors and education policymakers should invest in teaching innovations that diversify the learning environment towards improving surgeons' performance. Further research focusing on standardisation and validation of novel teaching methods is also recommended.

The take-home messages of the study are:

- The digital teaching method is more effective than the traditional teaching method for surgical procedure cognitive skills
- Trainees have a higher satisfaction level with the digital teaching method
- Trainees considered the digital teaching method clearer in teaching surgical procedure cognitive skills.

The results of this study have been presented at two international conferences, resulting in rich discussions regarding further collaboration, implementation, and local challenges. The audience at this researcher's conferences included surgical trainees, specialists, and other allied specialities. The discussions contributed to the study and the production of this thesis. The abstract of the presentations is published in a peer-reviewed journal, and this thesis will further be published in a peer-reviewed journal.

In conclusion: The researcher believes that the results of this study pave the way for further studies, the improvement of surgical curricula, and, ultimately, better surgical care outcomes.

Future research

The researcher suggests the following topics for future research:

- Intraoperative performance of trainees following prior cognitive skills training.

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- Impact of systematic and sequential surgical cognitive skills training on patient outcomes.
- Validation of a digital teaching method for Surgical procedure cognitive skills.

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MJM conceived the original idea. Together with MB, IL, they developed the theory and performed the computations. MB and IL supervised the research work. In addition, LM verified the study design and analytical methods.

MB and IL participated in supervising the manuscript writing with support from statistical support from LM.

All authors discussed the results and contributed to the final thesis and the interpretation of the results.

Conflict of interest statements

The authors have no conflict of interest.

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References

1. Payne T, Toms JD, Zaidi A, Thrumurthy SG. The history of surgery and surgical training in the UK. Pakistan journal of medical sciences. 2021;37(5):1532-5.
2. Robinson JO. The barber-surgeons of London. J Archives of Surgery. 1984;119(10):1171-5.
3. Cameron JL. William Stewart Halsted. Our surgical heritage. J Annals of surgery. 1997;225(5):445.
4. Sealy WC. Halsted is dead: Time for change in graduate surgical education. Current Surgery. 1999;56(1):34-9.
5. Grillo HC. Edward D. Churchill and the "rectangular" surgical residency. J Surgery. 2004;136(5):947-52.
6. Grover BT, Kothari SN. Fellowship training: need and contributions. J Surgical Clinics. 2016;96(1):47-57.
7. Rashid P. Surgical education and adult learning: Integrating theory into practice. F1000Research. 2017;6:143.
8. Franzese CB, Stringer SP. The evolution of surgical training: perspectives on educational models from the past to the future. J Otolaryngologic Clinics of North America. 2007;40(6):1227-35.
9. Degiannis E, Oettle GJ, Smith MD, Veller MG. Surgical education in South Africa. J World journal of surgery. 2009;33(2):170-3.
10. Gopalan P, Daniel C, Analgesia. The history of the College of Anaesthetists of South Africa. J Southern African Journal of Anaesthesia. 2022;28(2):52-60.
11. Kodwavwala Y. History of the association of surgeons of east Africa (ASEA) and the college of surgeons of east, central and southern Africa (COSECSA). J COSECSA 10th Anniversary, Kigali, Rwanda. 2018:1-20.
12. Bode C, Olatosi J, Ademuyiwa A. Accreditation of training programmes by the West African College of Surgeons. J Journal of the West African College of Surgeons. 2012;2(2):95.
13. Bode CO, Nwawolo CC, Giwa-Osagie OF. Surgical education at the west African College of Surgeons. J World journal of surgery. 2008;32(10):2162-6.
14. Monkhouse S. Learning in the surgical workplace: necessity not luxury. J The clinical teacher. 2010;7(3):167-70.
15. Brygel M. Surgical Skills Training With Models. J World Family Medicine. 2018;16(8):46-7.
16. Probst P, Grummich K, Harnoss JC, Hüttner FJ, Jensen K, Braun S, et al. Placebo-Controlled Trials in Surgery: A Systematic Review and Meta-Analysis. Medicine. 2016;95(17):e3516.
17. Kotsis SV, Chung KC, surgery r. Application of see one, do one, teach one concept in surgical training. J Plastic. 2013;131(5):1194.
18. Lubowitz JH, Provencher MT, Brand JC, Rossi MJ. The apprenticeship model for surgical training is inferior. J Arthroscopy. 2015;31(10):1847-8.
19. Smith CC, Gordon CE, Feller-Kopman D, Huang GC, Weingart SN, Davis RB, et al. Creation of an innovative inpatient medical procedure service and a method to evaluate house staff competency. J Journal of general internal medicine. 2004;19(5p2):510-3.
20. Mason W, Strike P. See one, do one, teach one—is this still how it works? A comparison of the medical and nursing professions in the teaching of practical procedures. J Medical teacher. 2003;25(6):664-6.

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21. Sachdeva AK, Bell Jr RH, Britt LD, Tarpley JL, Blair PG, Tarpley MJ. National efforts to reform residency education in surgery. J Academic Medicine. 2007;82(12):1200-10.
22. Sullivan ME, Ortega A, Wasserberg N, Kaufman H, Nyquist J, Clark R. Assessing the teaching of procedural skills: can cognitive task analysis add to our traditional teaching methods? J The American Journal of Surgery. 2008;195(1):20-3.
23. Tirapelle LA. The effect of cognitive task analysis based instruction on surgical skills expertise and performance: University of Southern California; 2010.
24. Knol J, Keller DS. Cognitive skills training in digital era: a paradigm shift in surgical education using the TaTME model. J The Surgeon. 2019;17(1):28-32.
25. Cowan B, Sabri H, Kapralos B, Cristancho S, Moussa F, Dubrowski A, editors. SCETF: Serious game surgical cognitive education and training framework. 2011 IEEE international games innovation conference (IGIC); 2011: IEEE.
26. Kohls-Gatzoulis JA, Regehr G, Hutchison C. Teaching cognitive skills improves learning in surgical skills courses: a blinded, prospective, randomized study. J Canadian journal of surgery. 2004;47(4):277.
27. Levin AS, Haq IU, LaPorte DM. Pre-course cognitive training using a smartphone application in orthopaedic intern surgical skills “boot camps”. J Journal of orthopaedics. 2018;15(2):506-8.
28. Raîche I, Hamstra S, Gofton W, Balaa F, Dionne ÉC. Cognitive challenges of junior residents attempting to learn surgical skills by observing procedures. J The American Journal of Surgery. 2019;218(2):430-5.
29. Alken A, Luursema J-M, Weenk M, Yauw S, Fluit C, van Goor H. Integrating technical and non-technical skills coaching in an acute trauma surgery team training: Is it too much? J The American Journal of Surgery. 2018;216(2):369-74.
30. Crebbin W, Beasley S, Tobin S, Guest G, Duvivier R, Watters D. Judgement: clinical decision-making as a core surgical competency. ANZ Journal of Surgery. 2019;89(6):760-3.
31. Hoque M. Three Domains of Learning: Cognitive, Affective and Psychomotor2017. 45-51 p.
32. Adams NE. Bloom's taxonomy of cognitive learning objectives. Journal of the Medical Library Association. 2015;103(3):152-3.
33. Anderson LW, Bloom BS. A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives: Longman; 2001.
34. Forehand M. Bloom’s taxonomy. J Emerging perspectives on learning, teaching,
technology. 2010;41(4):47-56.
35. Armstrong PJVUCfT. Bloom’s taxonomy. 2016.
36. Krathwohl DRJTip. A revision of Bloom's taxonomy: An overview. 2002;41(4):212-8.
37. Bloom BSJNYM. Taxonomy of educational objectives. Vol. 1: Cognitive domain. 1956:20-4.
38. Prakash ES, Narayan KA, Sethuraman KR. Student perceptions regarding the usefulness of explicit discussion of "Structure of the Observed Learning Outcome" taxonomy. Adv Physiol Educ. 2010;34(3):145-9.
39. Williams BW, Byrne PD, Welindt D, Williams MV. Miller's Pyramid and Core Competency Assessment: A Study in Relationship Construct Validity. J Contin Educ Health Prof. 2016;36(4):295-9.

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40. Driver R, Jr., Grose B, Serafini M, Cottrell S, Sizemore D, Vallejo M. A Focused Observation Tool Using Dreyfus Stages of Skill Acquisition as an Evaluative Scale. W V Med J. 2017;113(2):36-41.
41. Roberts KE, Bell RL, Duffy AJ. Evolution of surgical skills training. World J Gastroenterol. 2006;12(20):3219-24.
42. Grantcharov TP, Reznick RK. Teaching procedural skills. J Bmj. 2008;336(7653):1129-31.
43. Burch N. Four stages of competence. J Gordon Training International. 1970.
44. Whimbey A. Teaching sequential thought: The cognitive-skills approach. J The Phi Delta Kappan. 1977;59(4):255-9.
45. Aggarwal R, Grantcharov TP, Eriksen JR, Blirup D, Kristiansen VB, Funch-Jensen P, et al. An evidence-based virtual reality training program for novice laparoscopic surgeons. J Annals of surgery. 2006;244(2):310.
46. Raiche I, Hamstra S, Gofton W, Balaa F, Dionne E. Cognitive challenges of junior residents attempting to learn surgical skills by observing procedures. Am J Surg. 2019;218(2):430-5.
47. Pedowitz RA, Marsh LJ. Motor skills training in orthopaedic surgery: a paradigm shift toward a simulation-based educational curriculum. J JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2012;20(7):407-9.
48. Atesok K, Mabrey JD, Jazrawi LM, Egol KA. Surgical simulation in orthopaedic skills training. J JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2012;20(7):410-22.
49. Katz A. Resisting resistance to change: a critical analysis of the structure of surgical residency training programs: University of Pittsburgh; 2013.
50. Grunwald T, Corsbie-Massay C. Surgical Multimedia Academic, Research and Training (S.M.A.R.T.) tool: a comparative analysis of cognitive efficiency for two multimedia learning interfaces that teach the pre-procedural processes for carpal tunnel release. Stud Health Technol Inform. 2006;119:165-9.
51. Motsumi M, Ayane G, Bedada A. The role of Moodle-based surgical skills illustrations using 3D animation in undergraduate training. Afr J Health Professions Educ 2019;11(4):149-52.
52. Shariff U, Kullar N, Haray P, Dorudi S, Balasubramanian S. Multimedia educational tools for cognitive surgical skill acquisition in open and laparoscopic colorectal surgery: a randomized controlled trial. J Colorectal Disease. 2015;17(5):441-50.
53. Ahmet A, Gamze K, Rustem M, Sezen KA. Is video-based education an effective method in surgical education? A systematic review. J Journal of surgical education. 2018;75(5):1150-8.
54. Shariff U, Seretis C, Lee D, Balasubramanian SP. The role of multimedia in surgical skills training and assessment. Surgeon. 2016;14(3):150-63.
55. Gambadauro P, Magos A. Digital video recordings for training, assessment, and revalidation of surgical skills. Surg Technol Int. 2010;20:36-9.
56. Han JJ, Patrick WL. See one-practice-do one-practice-teach one-practice: The importance of practicing outside of the operating room in surgical training. J Thorac Cardiovasc Surg. 2019;157(2):671-7.
57. Yeung C, McMillan C, Saun TJ, Sun K, D'Hondt V, von Schroeder HP, et al. Developing Cognitive Task Analysis-based Educational Videos for Basic Surgical Skills in Plastic Surgery. J Surg Educ. 2017;74(5):889-97.
58. Dhulipalla R, Marella Y, Katuri KK, Nagamani P, Talada K, Kakarlapudi A. Effect of 3D animation videos over 2D video projections in periodontal health

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education among dental students. J Int Soc Prev Community Dent. 2015;5(6):499-505.
59. Erolin C. Medical illustration in the 21st century and beyond. J Medical Writing. 2020;29:6-10.
60. Vernon T, Peckham D. The benefits of 3D modelling and animation in medical teaching. J Journal of Audiovisual media in Medicine. 2002;25(4):142-8.
61. Saettler P. A history of instructional technology. ERIC
1968.
62. Biggs J, Tang C, editors. Applying constructive alignment to outcomes-based teaching and learning. Training material for “quality teaching for learning in higher education” workshop for master trainers, Ministry of Higher Education, Kuala Lumpur; 2010.
63. Biggs J, editor Constructive alignment. Background notes to support a seminar given by Professor John Biggs jbiggs@ bigpond com ASSESSING LANGUAGE OR CONTENT; 2001.
64. van der Vleuten C, Lindemann I, Schmidt L. Programmatic assessment: the process, rationale and evidence for modern evaluation approaches in medical education. Med J Aust. 2018;209(9):386-8.
65. Schuwirth L, van der Vleuten C, Durning SJ. What programmatic assessment in medical education can learn from healthcare. Perspect Med Educ. 2017;6(4):211-5.
66. Le Grange L, Reddy C. Continuous assessment: An introduction and guidelines to implementation: Juta and Company Ltd; 1998.
67. Crebbin W, Beasley SW, Watters DA. Clinical decision making: how surgeons do it. J ANZ journal of surgery. 2013;83(6):422-8.
68. Madani A, Watanabe Y, Feldman LS, Vassiliou MC, Barkun JS, Fried GM, et al. Expert intraoperative judgment and decision-making: defining the cognitive competencies for safe laparoscopic cholecystectomy. J Journal of the American College of Surgeons. 2015;221(5):931-40. e8.
69. Alharahsheh HH, Pius A. A review of key paradigms: Positivism VS interpretivism. J Global Academic Journal of Humanities Social Sciences. 2020;2(3):39-43.
70. Taylor PC, Medina M. Educational research paradigms: From positivism to pluralism. J College Research Journal. 2011;1(1):1-16.
71. Park YS, Konge L, Artino AR. The positivism paradigm of research. J Academic Medicine. 2020;95(5):690-4.
72. Slootmaker A, Kurvers H, Hummel H, Koper R. Developing scenario-based serious games for complex cognitive skills acquisition:: Design, development and evaluation of the EMERGO platform. Journal of Universal Computer Science. 2014;20(4):561-82.
73. Fernández-Batanero JM, Román-Graván P, Montenegro-Rueda M, López-Meneses E, Fernández-Cerero J. Digital teaching competence in higher education: A systematic review. Education Sciences. 2021;11(11):689.
74. Grunwald T, Corsbie-Massay C. Surgical Multimedia Academic, Research and Training (SMART) Tool. J Medicine Meets Virtual Reality 14. 2006:165.
75. Bouchey B, Castek J, Thygeson J. Multimodal learning. Innovative Learning Environments in STEM Higher Education: Opportunities, Challenges, Looking Forward. 2021:35-54.

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76. Lu SC, Cheng YC, Chan PT. Using ADDIE Model to Develop a Nursing Information System Training Program for New Graduate Nurse. Stud Health Technol Inform. 2016;225:969-70.
77. Hsu TC, Lee-Hsieh J, Turton MA, Cheng SF. Using the ADDIE model to develop online continuing education courses on caring for nurses in Taiwan. J Contin Educ Nurs. 2014;45(3):124-31.
78. Reinbold S. Using the ADDIE model in designing library instruction. Med Ref Serv Q. 2013;32(3):244-56.
79. Cheung L. Using the ADDIE model of instructional design to teach chest radiograph interpretation. J Journal of Biomedical Education. 2016;2016:1-6.
80. Peterson C. Bringing ADDIE to life: Instructional design at its best. J Journal of Educational Multimedia Hypermedia. 2003;12(3):227-41.
81. Sayfouri N. Evaluation of the learning management system using students' perceptions. Med J Islam Repub Iran. 2016;30:460.
82. Mahoney NR, Boland MV, Ramulu PY, Srikumaran D. Implementing an electronic learning management system for an Ophthalmology residency program. BMC Med Educ. 2016;16(1):307.
83. Back DA, Behringer F, Haberstroh N, Ehlers JP, Sostmann K, Peters H. Learning management system and e-learning tools: an experience of medical students' usage and expectations. Int J Med Educ. 2016;7:267-73.
84. Gossman R. The Animation Production Process. J Recuperado de 2011.
85. DiNardo J. Natural experiments and quasi-natural experiments. Microeconometrics: Springer; 2010. p. 139-53.
86. Pape-Koehler C, Immenroth M, Sauerland S, Lefering R, Lindlohr C, Toaspern J, et al. Multimedia-based training on Internet platforms improves surgical performance: a randomized controlled trial. Surgical endoscopy. 2013;27:1737-47.
87. Wallace L, Raison N, Ghumman F, Moran A, Dasgupta P, Ahmed K. Cognitive training: How can it be adapted for surgical education? The Surgeon. 2017;15(4):231-9.
88. Kim S, Choi S, Seo M, Kim DR, Lee K. Designing a Clinical Ethics Education Program for Nurses Based on the ADDIE Model. Res Theory Nurs Pract. 2020;34(3):205-22.
89. Miller GT, Motola I, Brotons AA, Issenberg SB. Preparing for the worst. A review of the ADDIE simulation model for disaster-response training. JEMS. 2010;35(9):suppl 11-3.
90. Boot WR, Charness N, Czaja SJ, Sharit J, Rogers WA, Fisk AD, et al. Computer proficiency questionnaire: assessing low and high computer proficient seniors. J The Gerontologist. 2015;55(3):404-11.
91. Flin R, Youngson G, Yule S, Safety. How do surgeons make intraoperative decisions? J BMJ Quality. 2007;16(3):235-9.
92. Hall J, Ellis C, Hamdorf J. Surgeons and cognitive processes. J Journal of British Surgery. 2003;90(1):10-6.
93. Flin R, Yule S, Paterson-Brown S, Maran N, Rowley D, Youngson G. Teaching surgeons about non-technical skills. J The Surgeon. 2007;5(2):86-9.
94. Yule S, Flin R, Maran N, Rowley D, Youngson G, Paterson-Brown S. Surgeons’ non-technical skills in the operating room: reliability testing of the NOTSS behavior rating system. J World journal of surgery. 2008;32:548-56.
95. Roberts KE, Bell RL, Duffy AJ. Evolution of surgical skills training. J World journal of gastroenterology: WJG. 2006;12(20):3219.
96. Gupta K. A practical guide to needs assessment: John Wiley & Sons; 2011.

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97. Black K. Business statistics: for contemporary decision making: John Wiley & Sons; 2023.
98. Palinkas LA, Horwitz SM, Green CA, Wisdom JP, Duan N, Hoagwood K. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. Administration policy in mental health mental health services research. 2015;42:533-44.
99. Csikszentmihalyi M, Larson R. Validity and reliability of the experience-sampling method. The Journal of nervous mental disease. 1987;175(9):526-36.
100. Alias A, Ariffin K, Mohamad Bhkari N, Ahmad Zaini A, editors. Aligning assessment to course outcomes in OBE: Comparing the application of bloom's taxonomy in final examination papers in UiTM. Konferensi Akademik; 2011.
101. Association WM. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. J Jama. 2013;310(20):2191-4.
102. Miracle VA. The Belmont Report: The triple crown of research ethics. Dimensions of critical care nursing. 2016;35(4):223-8.
103. Barrow JM, Brannan GD, Khandhar PB. Research ethics. 2017.
104. Gallagher AG, Ritter EM, Champion H, Higgins G, Fried MP, Moses G, et al. Virtual reality simulation for the operating room: proficiency-based training as a paradigm shift in surgical skills training. J Annals of surgery. 2005;241(2):364.
105. Saputra DIS, Manongga D, Hendry H, editors. Animation as a Creative Industry: State of The Art. 2021 IEEE 5th International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE); 2021: IEEE.
106. Chan KL. A proposed character animation workflow for digital production arts with preparation for cloth dynamics: Clemson University; 2007.
107. Cho K, Seo J, Kang J, Lee J, Kim S, Park J, et al., editors. Render verse: Hybrid render farm for cluster and cloud environments. 2014 7th International Conference on Control and Automation; 2014: IEEE.
108. Zimmerman DW. Teacher’s corner: A note on interpretation of the paired-samples t test. J Journal of Educational Behavioral Statistics. 1997;22(3):349-60.
109. Kirkpatrick JD, Kirkpatrick WK. Kirkpatrick's four levels of training evaluation: Association for Talent Development; 2016.
110. Girden ER. ANOVA: Repeated measures: sage; 1992.
111. Brookfield SD. Self-directed learning. International handbook of education for the changing world of work: Bridging academic and vocational learning: Springer; 2009. p. 2615-27.
112. Sankey M, Birch D, Gardiner MW. Engaging students through multimodal learning environments: The journey continues. Proceedings of the 27th Australasian Society for Computers in Learning in Tertiary Education. 2010:852-63.

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1 Appendix A

Dr Mpapho Motsumi

From:	MOGOROSI, Merapelo (Mrs)
Sent:	01 February 2021 15:49
To:	Dr Mpapho Motsumi
Cc:	Mogokgwane, Tumelo T.O.
Subject:	RE: Moodle Course Piloting Surgical Cognitive Skills Training

Good day and compliments,

The course has been created as requested.

Regards,
Merapelo
5234

Sent from Mail for Windows 10

From: Dr Mpapho Motsumi
Sent: Monday, 01 February 2021 11:10 AM
To: Mogokgwane, Tumelo T.O.; MOGOROSI, Merapelo (Mrs)
Subject: RE: Moodle Course Piloting Surgical Cognitive Skills Training

Dear Tumelo Mogokgwane and Merapelo Mogorosi

Ngwaga o mosha

Kindly assist. I note that the Moodle interface has been upgraded. I had a course that was manually created for my PhD project as per the communication below. That course does not appear anymore since the upgrade. Kindly relink me to the course. Course = "Moodle Course Piloting Surgical Cognitive Skills Training".

I appreciate you assistance

Dr. M. Motsumi 72858907

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From: Mogokgwane, Tumelo T.O. <mogokgwanet@UB.AC.BW>
Sent: 05 August 2020 15:53
To: Dr Mpapho Motsumi <motsumim@ub.ac.bw>; josephmotsumi@yahoo.com
Cc: TAU, T.T. (MS.) <TAUTT@UB.AC.BW>; MOGOROSI, Merapelo (Mrs) <mogorosim@UB.AC.BW>
Subject:

Good day,

Please note that the above mentioned course has been created and you are linked as a teacher.

You will be able to edit the course settings and add UB students to the course, but non UB students will have to be discussed with the Moodle team first.

You can reach us at mogokgwanet@ub.ac.bw or mogorosim@ub.ac.bw for any further.

1

Regards,

Tumelo Mogokgwane
There is currently no vaccine or therapeutics for COVID-19. Prevention is better than cure. Wash your hands with clean water and soap for 20 seconds as frequently as possible. "Motho le motho kgomo" is the founding culture of our University. The little you contribute can go a long way in making this University successful. Save water, Save power, Save paper, cut unnecessary costs and MOVE the University forward.

Appendix 1.1 Notification of course creation by UB IT Department.
Click to go back

I agree to participate in this study

Enter your full name (first name followed by surname)

Appendix 1.2 Consent form.
Click to go back

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Age (years)

Gender

Position at work

Training institute that you are registered with.

Workplace / Health facility

Year of training as a residents in Surgery

Number of years spent working in the Surgical department post internship

Appendix 1.3 Demographics questionnaire form.
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I can use a mouse

I can use a computer keyboard to type:

I can open emails

I can send emails

I can find information about local community resources on the Internet

I can find information about my hobbies and interests on the Internet

I can use a computer to watch movies and videos

Which of the following hardware do you have access to? (You may choose more than one option)
☐ Cell phone ☐ Laptop ☐ Desktop ☐ Tablet ☐ Gaming console ☐ Other

If your answer to the preceding question includes "Other". Name the other hardware.

How do you access the internet? Indicate by selecting one or more of the provided options.
☐ Residential internet access point ☐ Internet café ☐ Computer centre ☐ Cell phone data bundle ☐ Public internet access points ☐ Other

If your answer to the preceding question included "Other". Specify 'other'.

How often do you use a computer?

If your answer to the preceding question is "Other". Specify 'other'.

I can use a computer to play games

How often do you play computer games?

If your answer to the preceding question is "Other", specify "Other".

I can use a computer to listen to music

Appendix 1.4 Computer proficiency questionnaire form.

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Kindly complete the following survey regarding which subtopics should be covered and to what extend, before observing or attempting a surgical procedure in the operating room.

PSCST

Is covering an introduction topic relevant before observing a surgical procedure?

How extensive should the introduction topic be?

Is covering a topic on indications for a surgical procedure relevant before observing it?

How extensive should the indications topic be?

Is covering a topic on contra-indications for a surgical procedure relevant before observing it.

How extensive should the contra-indications topic be

Is covering a topic on preoperative preparation for a surgical procedure relevant before observing it?

How extensive should the topic on preoperative preparation be?

Is having an illustrative demonstration of positioning for a surgical procedure relevant before observing it?

How extensive should the illustrative demonstration of positioning be.

Is having an illustrative demonstration of exposure and access for a surgical procedure relevant before observing it?

How extensive should the illustrative demonstration of exposure and access be?

Is having an illustrative demonstration of operative steps for a surgical procedure relevant before observing it?

How extensive should the illustrative demonstration of operative steps be.

Is having an illustrative demonstration of closure after for a surgical procedure relevant before observing it?

How extensive should the illustrative demonstration of closure be?

Is covering a topic on postoperative management for a surgical procedure relevant before observing it?

How extensive should the postoperative management topic be?

Is covering a topic on complications and their management for a surgical procedure relevant before observing it?

How extensive should the complications and their management topic be?

If you have any topic you consider relevant for trainees to cover before observing a surgical procedure in the operating room, kindly: 1) Name the topic, a) indicate whether you would want it to be covered briefly or in detail.

Appendix 1.5 Needs assessment questionnaire form.

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The traditional teaching method helped me to better understand the topic

The new teaching method (Video illustration) helped me to better understand the topic

I feel like the traditional teaching method helped me achieve the learning outcomes.

I feel like the new teaching method (Video illustration) helped me achieve the learning outcomes.

Overall, I am satisfied with the traditional teaching method.

Overall, I am satisfied with the new teaching method (Video illustration).

I would recommend the new teaching method (video illustration) to a colleague

I recommend the adoption of the new teaching method (video illustration)

Assessments in the new teaching method (Video illustration) facilitated learning .

Any comments

Which teaching method would you prefer
◉ Not selected ○ Traditional teaching method only. ○ The new teaching method (animation + embedded assessments). ○ Hybrid (a combination of the traditional and the new teaching method)

What teaching / learning material did you use during traditional learning session?

For the procedure you learnt using the new teaching method, how many times had you observed it in the operating room?
◉ Not selected ○ Never ○ Once ○ 2-5 times ○ 6 - 10 times ○ > 10 times

For the procedure you learnt using the new teaching method, how many times had you performed it in the operating room ?
◉ Not selected ○ Never ○ Once ○ 2-5 times ○ 6 - 10 times ○ > 10 times

For the procedure you learnt using the traditional teaching method, how many times had you performed it in the operating room ?
◉ Not selected ○ Never ○ Once ○ 2-5 times ○ 6 - 10 times ○ > 10 times

For the procedure you learnt using the traditional teaching method, how many times had you observed it in the operating room ?
◉ Not selected ○ Never ○ Once ○ 2-5 times ○ 6 - 10 times ○ > 10 times

Appendix 1.6 Satisfaction level and procedure clarity questionnaire.

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2 Appendix B

Appendix 2.1 SRS oral presentation acceptance letter.

Click here to go back

Surgical Research Society of Southern Africa

11 June 2022

Dr M Motsumi
Department of Surgery
Botswana

motsumim@ub.ac.bw

Dear Dr Motsumi

RE ABSTRACT: A COMPARISON OF SURGICAL PROCEDURE COGNITIVE SKILLS ACQUISITION

Thank you for submitting your abstract for presentation at the Surgical Research Society Congress to be held 08-09 June 2022. We are pleased to inform you that it has been accepted for presentation.

Please note that 8 minutes are allowed for presentations followed by a 2-minute discussion. A copy of the programme indicating the time of your presentation will be forwarded as soon as finalised.

Please visit the website surgicalresearch.co.za/srs-meeting-2022 for registration and payment and please send proof of payment to mathilda.howard@smu.ac.za and a copy to susanparkes@mweb.co.za.

Kind regards
Yours sincerely

MZ KOTO, *MBChB(MED); FACS; FCS(SA); FCS(ECSA); Cert GIT(SA); FCR(HARVARD); PhD*
CHAIRMAN: LOC

President: President: Dr J Edge; Secretary: Dr J Devar
Treasurer: Dr T Augustine
Administration Officer: Mrs S Parkes
Secretariat: Room 9S07A, Wits Medical School, 7 York Road, Parktown 2193, Johannesburg, South Africa. Postnet 199, Private Bag X2600, Houghton. 2041.
Telephone: +27 0835366806 *Email:* assa@worldonline.co.za or susanparkes@mweb.co.za

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Appendix 2.2 COSECSA oral presentation acceptance letter.

Click here to go back

NAMIBIAN SURGICAL SOCIETY

NSS & COSECSA

COLLEGE OF SURGEONS · East · Central · Southern · Africa · 19 99

Date: November 7th, 2022

Abstract Acceptance Letter

Dear Dr. Motsumi

Thank you for the interest to present your abstract titled, *"A COMPARISON OF SURGICAL PROCEDURE COGNITIVE SKILLS ACQUISITION BETWEEN THE TRADITIONAL APPRENTICESHIP MODEL AND 3D ANIMATION WITH PROGRAMMATIC ASSESSMENT"* at the 22nd COSECSA Annual Scientific Conference, 7th – 9th December to be held at Safari Hotel, Windhoek, Namibia themed ***Timely Response to Current & Emerging Surgical Challenges on the Continent***.

On behalf of the Namibian Surgical Society organizing committee, I am pleased to inform you that your abstract was accepted for an oral presentation at the conference. Please inform any co-authors of the acceptance of this abstract. The specific details of the day, time and session of your presentation will be included in the finalized conference program.

Please note that the presentation must meet the following criteria:

1. **Language:** The presentation must be prepared in English, the official language of the conference.
2. **Presentation time:** 10 minutes will be allowed for your presentation. The Questions and Answers time will be conducted at the end of each specific session.
3. **Presentation file:** The presentation must be in PowerPoint format.
4. Presentation must be uploaded on the conference computer prior to the presentation session. There will be staff who will assisting in the computer room with the uploading of the presentations.

This letter is also aimed to be presented to the Consulate of Namibia in your country to support your application for visa.

Please note that there are no grants nor sponsorships from the NSS or COSECSA secretariat. Participants accepted to present are highly encouraged to seek or apply for sponsorship from their Ministry of Health or NGOs.

We look forward to welcome you in Namibia in December.

Yours sincerely,

On behalf of the 22nd COSECSA Conference Organizing Committee

Dr. Pueya Abdulrashid Nashidengo, Windhoek Central Hospital

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Appendix 2.3 Phase I manuscript acceptance letter.

Click here to go back

Track the status of your submission to Journal of Surgical Research

Track your Elsevier submission <no-reply@submissions.elsevier.com>
Fri 2024-01-12 01:39
To:Dr Mpapho Motsumi <motsumim@ub.ac.bw>

Manuscript Number: JSURGRES-D-23-02058
Manuscript Title: Phase I: Designing a digital teaching approach for surgical procedure cognitive skills.
Journal: Journal of Surgical Research

Dear MPAPHO MOTSUMI,

Your submitted manuscript is currently under review. You can track the status of your submission in Editorial Manager, or track the review status in more detail using Track your submission here:
https://track.authorhub.elsevier.com?uuid=efde7d6a-bbd5-4de8-ae23-58fe0e67ac34

This page will remain active until the peer review process for your submission is completed. You can visit the page whenever you like to check the progress of your submission. The page does not require a login, so you can also share the link with your co-authors.

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https://webapps.elsevier.cn/st-wechat/subscribe?signature=1705016248-e6173f949495c1c72664ca0aaa9b021e&uuid=efde7d6a-bbd5-4de8-ae23-58fe0e67ac34

We hope you find this service useful.

Kind regards,
Journal Office of Journal of Surgical Research
Elsevier B.V.

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Appendix 2.4 Phase II manuscript acceptance letter.

Click here to go back

Preview

From: MDE@sagepub.com

To: motsumim@ub.ac.bw, martin.brand@up.ac.za, lubbei@ceu.edu, lmokgathe@statsbots.org.bw

CC:

Subject: Journal of Medical Education and Curricular Development MDE-23-0158

Body: 20-Jul-2023

Dear Dr. Motsumi:

Your manuscript entitled "Phase II: A comparison of surgical procedure cognitive skills acquisition between the traditional apprenticeship and a digital teaching approach" has been successfully submitted online and is presently being given full consideration for publication in Journal of Medical Education and Curricular Development.

Your manuscript ID is MDE 23 0158.

You have listed the following individuals as authors of this manuscript:
Motsumi, Mpapho; Brand, Martin; Lubbe, Johanna; Mokgatlhe, Lucky

Please mention the above manuscript ID in all future correspondence or when calling the office for questions. If there are any changes in your street address or e-mail address, please log in to ScholarOne Manuscripts at https://mc.manuscriptcentral.com/meded and edit your user information as appropriate.

You can also view the status of your manuscript at any time by checking your Author Center after logging in to https://mc.manuscriptcentral.com/meded.

As part of our commitment to ensuring an ethical, transparent and fair peer review process Sage is a supporting member of ORCID, the Open Researcher and Contributor ID (https://orcid.org/). We encourage all authors and co authors to use ORCID IDs during the peer review process. If you have not already logged in to your account on this journal's ScholarOne Manuscripts submission site in order to update your account information and provide your ORCID identifier, we recommend that you do so at this time by logging in and editing your account information. In the event that your manuscript is accepted, only ORCID IDs validated within your account prior to acceptance will be considered for publication alongside your name in the published paper as we cannot add ORCID IDs during the Production steps. If you do not already have an ORCID ID you may login to your ScholarOne account to create your unique identifier and automatically add it to your profile.

Thank you for submitting your manuscript to Journal of Medical Education and Curricular Development.

Sincerely,
Anju Gond
Journal of Medical Education and Curricular Development
MDE@sagepub.com

Date Sent: 20-Jul-2023

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Appendix 2.5 Certificate of full registration and accreditation as an Assessor.

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BOTSWANA
Qualifications Authority

CERTIFICATE OF FULL REGISTRATION & ACCREDITATION

This is to certify that

Mpapho Motsumi

is registered as an

Assessor

Under the Botswana Qualifications Authority Act No 24 of 2013

24/05/2023
Date of Current Registration & Accreditation

23/05/2028
Expiry Date

Education Registrar

Chief Executive Officer

0002251

ASSESSOR NO: A02999

This Certificate should be used in conjunction with the Scope of Registration and Accreditation.

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Qualifications Authority

FULL REGISTRATION
SCOPE OF REGISTRATION & ACCREDITATION

NAME OF ASSESSOR: Mpapho Motsumi

ASSESSOR NO: A02999

DATE OF REGISTRATION & ACCREDITATION: 24/05/2023

DATE OF EXPIRY: 23/05/2028

Surgery - NCQF Level 8

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Chief Executive Officer

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Appendix 2.6 Certificate of full registration and accreditation as Moderator.

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SIGNATURE:

BOTSWANA
Qualifications Authority

CERTIFICATE
OF
FULL REGISTRATION & ACCREDITATION

This is to certify that

Mpapho Motsumi

is registered as a

Moderator

Under the Botswana Qualifications Authority Act No 24 of 2013

24/05/2023
Date of
Current Registration & Accreditation

23/05/2028
Expiry Date

Education Registrar

Chief Executive Officer

0001079

MODERATOR NO: M00566

This Certificate should be used in conjunction with the Scope of Registration and Accreditation.

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BOTSWANA
Qualifications Authority

FULL REGISTRATION

SCOPE OF REGISTRATION & ACCREDITATION

NAME OF MODERATOR: Mpapho Motsumi

MODERATOR NO: M00566

DATE OF REGISTRATION & ACCREDITATION: 24/05/2023

DATE OF EXPIRY: 23/05/2028

Surgery - NCQF Level 6

BOTSWANA QUALIFICATIONS AUTHORITY
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Chief Executive Officer

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Check the public register of accredited institutions to view the scope of accreditations of this institution.

[illegible]

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Appendix 2.7 Statistician Letter of Support

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STATISTICS BOTSWANA
Private Bag 0024, Gaborone, Botswana
Tel: (+267) 367 1300. Fax: (+267) 395 2201

LETTER OF STATISTICAL SUPPORT

This letter is to certify that the student, with the Name **Mpapho Motsumi a PhD candidate** at the **University of Pretoria, Department of Surgery** was assisted by me on his dissertation project titled: **A comparison of surgical procedure cognitive skills acquisition between the traditional apprenticeship and a digital approach**.

I started working with Dr Motsumi when I was still Head, Department of Statistics at the University of Botswana. Currently I work as Deputy Statistician General, at Statistics Botswana. This an organization tasked with custodianship of all official statistics in Botswana. I hereby confirm that I assisted with the statistical analysis of the data generated from the project.

The analytical tool that was used is a 2x2 crossover t-test that tests for procedure effect, period effect and interaction effect to achieve the objective(s) of the study.

Name: Lucky Mokgatlhe, PhD
Signature:
Institution: Statistics Botswana

Date: 14/02/2023
Tel: 267 72554903

REGIONAL OFFICE. Private Bag F193., Francistown . **Tel:** (+267) 241 5848. **Fax:** (+267) 241 7540

All correspondence should be addressed to Statistician General
Email.info@statsbots.org.bw **Website:** www.statsbots.org.bw

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Appendix 2.8 Expert English Editors Certificate

expertenglisheditorscc

CERTIFICATE

Expert English Editors CC 2007/147556/23
Member: J R Levey
editsa@gmail.com www.expertenglisheditors.co.za
P O Box 14686, Hatfield, 0028, South Africa (0)73 204 5392 /Cell +27 (0)82 862 3085

TO WHOM IT MAY CONCERN

This is to certify that this document has been edited for English style, language usage, logic and consistency; it is the responsibility of the author to manually accept or reject the suggested changes and interact with the comments to finalise the text and the references.

Title: **A Comparison of Surgical Procedure Cognitive Skills Acquisition Between the Traditional Apprenticeship and a Digital Teaching Approach**

Author: Dr MJ Motsumi

Degree: PhD (Surgery)

Institutions: Department of Surgery
University of Pretoria
South Africa

Yehuda Elkana Center for Teaching, Learning and
Higher Education Research
Central European University, Vienna Austria

Sincerely

Dr Felicity Horne, for Expert English Editors
B. A. (Wits); T.T.H.D (Wits); B.A. Hons (Unisa); M.A. (Unisa); D. Litt. et Phil. (Unisa)

2023-06-27

Members: J Levey. Reg. No: 2007/147556/23

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Appendix 2.9 Approval certificate – Annual renewal

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 18 March 2022 and Expires 18 March 2027.
- IORG #: IORG0001762 OMB No. 0990-0278 Approved for use through August 31, 2023

Faculty of Health Sciences **Research Ethics Committee**

19 January 2023

Approval Certificate
Annual Renewal

Dear Dr M Motsumi,

Ethics Reference No.: 629/2020 – Line 2
Title: A comparison of surgical procedure cognitive skills acquisition between the traditional apprenticeship model and 3D animation with programmatic assessment.

The **Annual Renewal** as supported by documents received between 2022-11-16 and 2023-01-18 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2023-01-18 as resolved by its quorate meeting.

Please note the following about your ethics approval:

- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2024-01-19.
- Please remember to use your protocol number (629/2020) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

On behalf of the FHS REC, Dr R Sommers
MBChB, MMed (Int), MPharmMed, PhD
***Deputy Chairperson** of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria*

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)

Research Ethics Committee
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Fakulteit Gesondheidswetenskappe
Lefapha la Disaense tša Maphelo

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Appendix 2.10 Approval certificate - Amendment

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH GCP guidelines and has US Federal wide Assurance.

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Faculty of Health Sciences **Research Ethics Committee**

19 January 2023

Approval Certificate
Amendment

Dear Dr M Motsumi,

Ethics Reference No.: 629/2020 – Line 3
Title: A comparison of surgical procedure cognitive skills acquisition between the traditional apprenticeship model and 3D animation with programmatic assessment.

The **Amendment** as supported by documents received between 2022-12-13 and 2023-01-18 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2023-01-18 as resolved by its quorate meeting.

Please note the following about your ethics approval:

- Please remember to use your protocol number (629/2020) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

Researcher note: Be sure that PhD. Committee also approves the amendment.

We wish you the best with your research.

Yours sincerely

On behalf of the FHS REC, Dr R Sommers
MBChB, MMed (Int), MPharmMed, PhD
***Deputy Chairperson** of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria*

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health).

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Appendix 2.11 Ph.D. Committee title amendment approval letter

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

16 January 2023

Prof M Brand
Department of Surgery
Faculty of Health Sciences

Dear Prof Brand

Student: M Motsumi (PhD Surgery)
Title: A comparison of surgical procedure cognitive skills acquisition between the traditional apprenticeship and a digital approach

RE: AMENDMENT

The title amendment for the above protocol has been approved by the PhD Committee.

With kind regards,

Martin Brand
Chair: PhD Committee

Email: martin.brand@up.ac.za
Tel +27 (0)12 354 2097

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Room 71107, Level 7, Bridge E, Steve Biko Academic Hospital
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