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A Cadaver Simulation Model for Basic Hand Surgery Training – a Design and Development Research

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Abstract
Background: The present skill training in hand surgery has limitations bound by complexity, difficulty of performing surgery and compromise on patient safety. Cadaveric Simulation has been described as a great solution to replace and augment real life experiences for training purposes.
Aim: To design an instructional model based on cadaveric simulation for imparting training in hand surgery for novice surgeons.
Material and methods: Analysis, design, development, implementation, and evaluation (ADDIE) instructional design model was used. A two-day workshop with ten cadavers attended by 48 participants and 6 faculty members. A questionnaire with 10 items was given for the assessment of the program module. The results were descriptively summarized, internal consistency and reliability were analysed through Cronbach alpha.
Results: Results of the survey indicated that participants were satisfied with the program and found it met their requirements and the course objectives.
Conclusion: The program is found to be beneficial in providing uniform, authentic, easy and feasible training in hand surgery to novice surgeons. The same will be implemented in large scale and further assessed.

Key Words
Cadaveric; Simulation; Hand; Surgery; Skill; Training

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Background

The teaching of surgery has traditionally been in the working environment in the form of a mentor-apprenticeship model, in which trained surgeons provide training to the learner[1].

The complexity and difficulty of performing surgery, the challenges of preserving patient safety, as well as an increasing lack of training opportunities have mandated the surgical faculty to reconsider the kind of training model, where acquisition of surgical skills can only be achieved solely in a working environment with live patients. These challenges required innovative strategies to incorporate recent technological advances like simulation, with more emphasis on competency-based assessment, the use of online courses and resources, and the development of a system that rewards faculty and scholarly activity in surgical education so as to improve the quality of training[2].

Simulation has been described as one of the solutions to replace and augment real life experiences for trainees to practice and learn. It allows for an immersive experience with interaction. It has been described as a technique and not a technology[3].

Open surgical simulators currently used include live animals, cadavers, bench models, virtual reality and software-based computer simulators. Cadaver models for surgical simulation has been shown to be effective in surgical training, particularly orthopaedic surgery[5].

Instructional design and technology are a systematic and scientific approach to the management of instructional and non-instructional processes and resources intended to improve learning and performance. This process enables optimal learning to be achieved by deliberately arranging sets of external events based on educational and training contexts[6]. An overall framework for designing learning programs is the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) instructional design model. The incorporation of the instructional design framework into surgical training programs will provide the foundation for designing and developing effective

programs that can be replicated and scaled to the various specialties.

The aim of this study was to design and develop a basic hand surgery training module for skill acquisition using a high-fidelity cadaver model incorporating the ADDIE model of instructional design.

Methods

This study was based on a design and development research framework, which is dedicated to the creation of new knowledge and the validation of existing practice is instructional[7].

A mixed methods approach was utilised with an exploratory sequential design[8]. This involved data collection sequentially, with the qualitative phase being the first step, and the quantitative method then sought to test and further quantify the initial qualitative findings.

Research Questions:

- How can an instructional program be designed and developed for basic hand surgery to produce competent performance among novices?
- Will the training programme provide the opportunity for authentic practice of surgical skills?
- Does the programme allow for ease of learning basic hand surgery?
- Is the module usable in the real world?

Design and Development of an instructional skills module for basic hand surgery

For this stage of the research, the ADDIE instructional design model (*Figure 1*) was used as the framework to design and develop a cadaveric workshop for the teaching of motor skills to perform basic hand surgery commonly seen in the community.

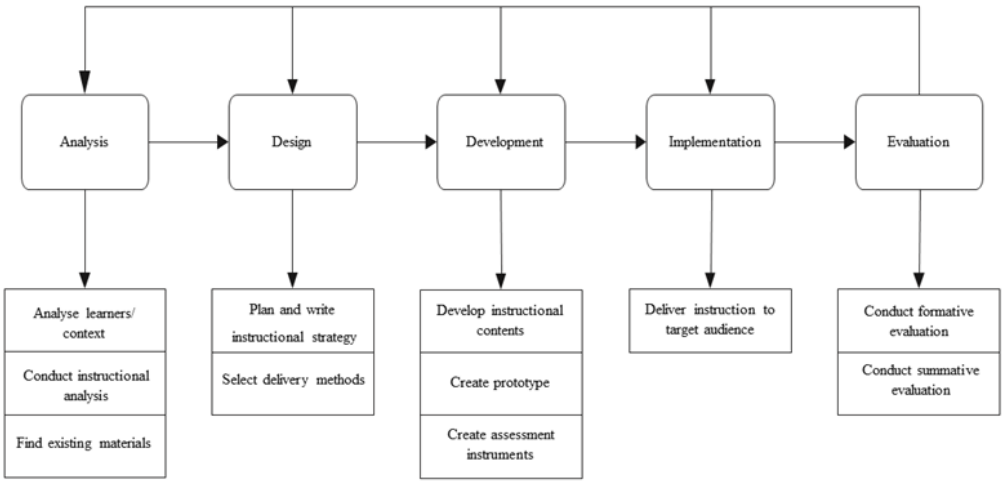

Figure 1: *Analysis, design, development, implementation, and evaluation (ADDIE) model phases and the steps during each phase.*

Analysis of Needs

A quantitative analysis from a previous study of the commonly performed procedures at a general hospital in Singapore was used to determine the index procedures to be covered in the program and the motor skills required to perform the surgical procedures[9]. Following which, the various tasks and subtasks needed to perform the procedure were described. An expert panel was used to validate the choice of the index procedures as an important need for training, and they were also involved in the description of the tasks and subtasks needed to perform that procedure. This led to the development of the learning outcomes for the procedures that included all the tasks and subtasks that were required.

Design and Development of Module

This study focused on designing the instructional content and tools for the module on basic hand surgery skills. The following framework details the process used in designing and developing the training module using the ADDIE model.

Table 1: *Design and Development process of Instructional Materials*

Research Design Concern	Recommended techniques used to address concern	How Study will Address Concern
Validity	Used experts with areas of specialisation for module review. Have participants verify reports of module use. Select doctors with varying levels of expertise to validate the module.	5 expert hand surgeons/ reviewers with broad knowledge of performance in hand surgery. Participants involved in the test of the tool confirmed their status as practicing hand surgery. Participants were selected from different grades to assess the modules that was developed.
Causal Inferences	Determine module's practicality. Determine module's effectiveness.	The module was made easily accessible via online access for the participants to review. Survey questions were deployed to ensure face and content validity.
Generalisation and Interpretation	Recognise "real world" constraints on module's use. Plan for module's independent use.	Non-Stakeholders were used to review and assess the module using an online survey tool. Made module accessible as an open educational resource for others to use.
Anticipating problems	Consider non-laboratory and different cultural contexts when analysing participant data.	In analyses, consideration was given that this is a small sample study, with its limitations.

Five experienced hand surgeons (as per the table below, each with more than five years in practice as consultants/specialists) were chosen as an expert review process, via purposeful sampling, to analyse the curriculum using an interview and survey for consensus. The review panel was also involved in the creation of the resource materials for the program which included the dissection and digital video recording of the procedures based on Mayer's Multimedia theory. These were conducted under the guidance of the instructional designer and subject matter expert RV.

Implementation

The products of the research (the content, sequence, and resources of the basic hand surgery skills training module) were then implemented as a 1.5-day cadaveric skill acquisition flipped workshop. The flipped classroom strategy involved participants studying the lectures at home with online videos and educational resources, and then engaging in interactive teacher-guided higher order learning in the class[10,11].

The whole module was deployed to an open online platform hosting a Moodle open source leaning management system. Participants were provided the link during registration to the workshop.

Evaluation

Evaluation was performed using surveys of the course content among the expert review panel and both participants and faculty during the course.

Results

To understand the community needs for emergency hand surgery, the results of a previously published study by the researcher was used (Sim, W. P., Ng, H. J. H., Tan, S., Bajaj, S. L., & Rajaratnam, V., 2019). This was a retrospective analysis of 1994 surgeries performed under regional anaesthesia from 2013-2016 at KTPH in Singapore. The average age of the patients was 46 years old with a male preponderance of 64%. A total of 96% of the patients had surgery done on a single limb and almost 40% of the surgeries were an emergency procedure. A detailed analysis of the type of operations performed was conducted using Pareto analysis of the frequencies of the types of surgery as shown in Figures 2 and 3.

Table 2: *Profile of Expert Reviewers*

Name	Institution	Expertise
DP	UK	Consultant Hand Surgeon
LWL	UK	Consultant Hand Surgeon
RV	Singapore	Consultant Hand Surgeon
TPY	Singapore	Consultant Hand Surgeon
BM	Singapore	Senior Resident Hand Surgeon

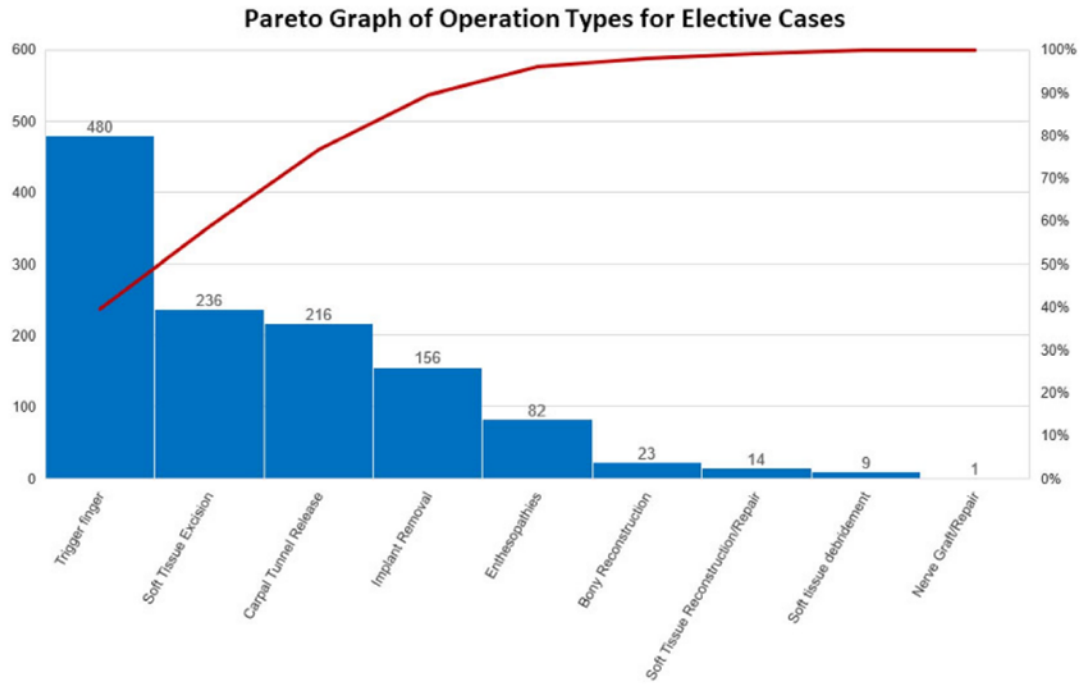

Figure 2: *Elective hand surgery cases*

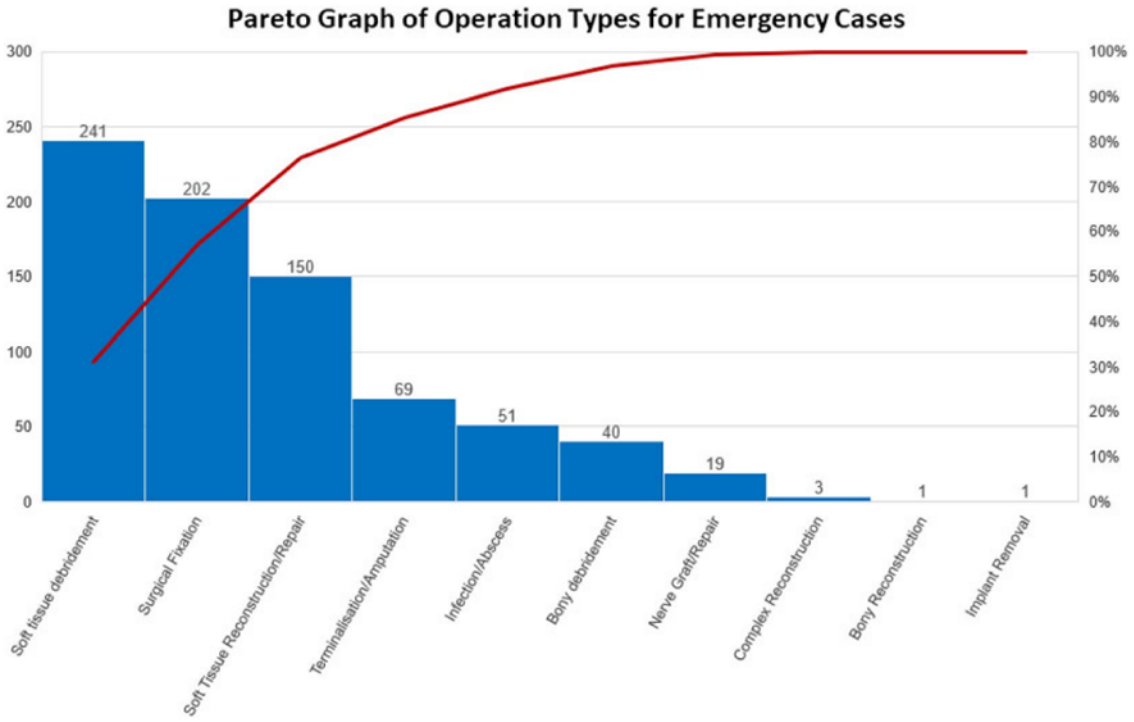

Figure 3: *Emergency hand surgery cases*

For the elective surgery procedures, the most common procedures from the Pareto analysis were trigger finger, excision of soft tissue and release carpal tunnel decompression, whereas in the emergency cases the procedures were soft tissue excisions, surgical fixation soft tissue reconstruction/repair and terminalisation of an amputation.

From this, a curriculum for the cadaver course was developed as online resources, a half day of short lectures and a whole day of hands cadaver simulation workshop. The program developed is as follows: -

Basic Hand Surgery Cadaver Course

Program Day 1

Functional anatomy of the hand
At the end of this lecture, you should be able to: -
- *Describe in detail the anatomy of the hand and wrist*
- *Plan skin incisions for exposure in common hand conditions*
- *Describe the anatomical basis of common hand presentations*

Hand assessment
At the end of this lecture, you should be able to: -
- *Confidently perform a targeted examination of the hand*
- *Understand the principles and basis of specific clinical tests in the hand*
- *Describe the various deformities and clinical presentation in the hand*

Principles of hand surgery
At the end of this lecture, you should be able to: -
- *Confidently take informed consents for common hand operations*
- *Explain the necessary surgical preparations and the use of specific equipment for hand surgery*
- *Describe the role of splinting and post-operative rehabilitation*

Regional Anaesthesia of the hand
At the end of this lecture, you should be able to: -
- *Describe the pharmacology, dose and toxicity of commonly used local anaesthetics agents*
- *Locate the surface marking of the peripheral nerves used in regional anaesthesia for hand surgery*
- *Confidently perform digital, median, ulnar and radial nerve and Biers blocks for hand and wrist surgery*

Tendinopathies of the hand
At the end of this lecture, you should be able to: -
- *Describe the pathology and presentation of the common tendinopathies in the hand*
- *Confidently diagnose and consent for surgery for these conditions*
- *Describe the management including surgery and post-operative rehabilitation.*

Entrapment neuropathies of the hand
At the end of this lecture you should be able to: -
- *Describe the pathology and presentation of the common neuropathies in the hand*
- *Confidently diagnose and consent for surgery for these conditions*
- *Describe the management including surgery and post-operative rehabilitation.*

Nailbed and Digital tip injuries
At the end of this lecture, you should be able to: -
- *Describe the presentations and classifications of digital tip and nail bed injuries*
- *Confidently consent for surgery for these conditions*
- *Able to describe a logical management plan including surgery and post-operative rehabilitation.*

Program Day 2 Cadaveric workshop

Workshop 1 Trigger finger release
- *Anatomy*
- *Markings*
- *Surgical Incision*
- *Dissection*
- *Definitive procedure*
- *Closure*

Workshop 2 De Quervain's release
- *Anatomy*
- *Markings*
- *Surgical Incision*
- *Dissection*
- *Definitive procedure*
- *Closure*

Workshop 3 Carpal Tunnel release
- *Anatomy*
- *Markings*
- *Surgical Incision*
- *Dissection*
- *Definitive procedure*
- *Closure*

Workshop 4 Cubital tunnel release
- *Anatomy*
- *Markings*
- *Surgical Incision*

- *Dissection*
- *Definitive procedure*
- *Closure*

Workshop 5 Ganglion excision
- *Anatomy*
- *Markings*
- *Surgical Incision*
- *Dissection*
- *Definitive procedure*
- *Closure*

Workshop 6 Full thickness skin graft for finger tip
- *Anatomy*
- *Markings*
- *Surgical Incision*
- *Dissection*
- *Definitive procedure*
- *Closure*

Workshop 7 V-Y plasty (Atasoy flap) for finger tip
- *Anatomy*
- *Markings*
- *Surgical Incision*
- *Dissection*
- *Definitive procedure*
- *Closure*

Workshop 8 Cross finger flap
- *Anatomy*
- *Markings*
- *Surgical Incision*
- *Dissection*
- *Definitive procedure*
- *Closure*

Workshop 9 Homodigital Island Flap
- *Anatomy*
- *Markings*
- *Surgical Incision*
- *Dissection*
- *Definitive procedure*
- *Closure*

Workshop 10 Mystery injury
Use the skills learnt from the workshop to assess and manage this injury on the cadaver.
Discuss with a faculty member your plan.

Optional Workshop Remedial / Heterodigital Island Flap
- *Anatomy*
- *Markings*
- *Surgical Incision*
- *Dissection*
- *Definitive procedure*
- *Closure*

The detailed program was presented to the expert review panel and there was a unanimous consensus that these index procedures were appropriate for the aims of the course.

The course was made available on the following link https://tinyurl.com/BASICCADAVER

The statistical analysis of the expert review panel of the course was as follows:

Overall average score for all items was 6.3 and a Cronbach alpha of 0.97.

Learner analysis
The target audience for this learning program are the junior doctors and residents who have attended a basic surgical training and are confident in their ability to use basic instruments and perform suturing.

48 participants of which 6 were faculty responded to the evaluation survey.

Statistical Analysis
Descriptive statistics were used to summarise the scores from the survey (Fig 4) and internal consistency and reliability of the survey was summarised with Cronbach alpha as shown in Table 3 below.

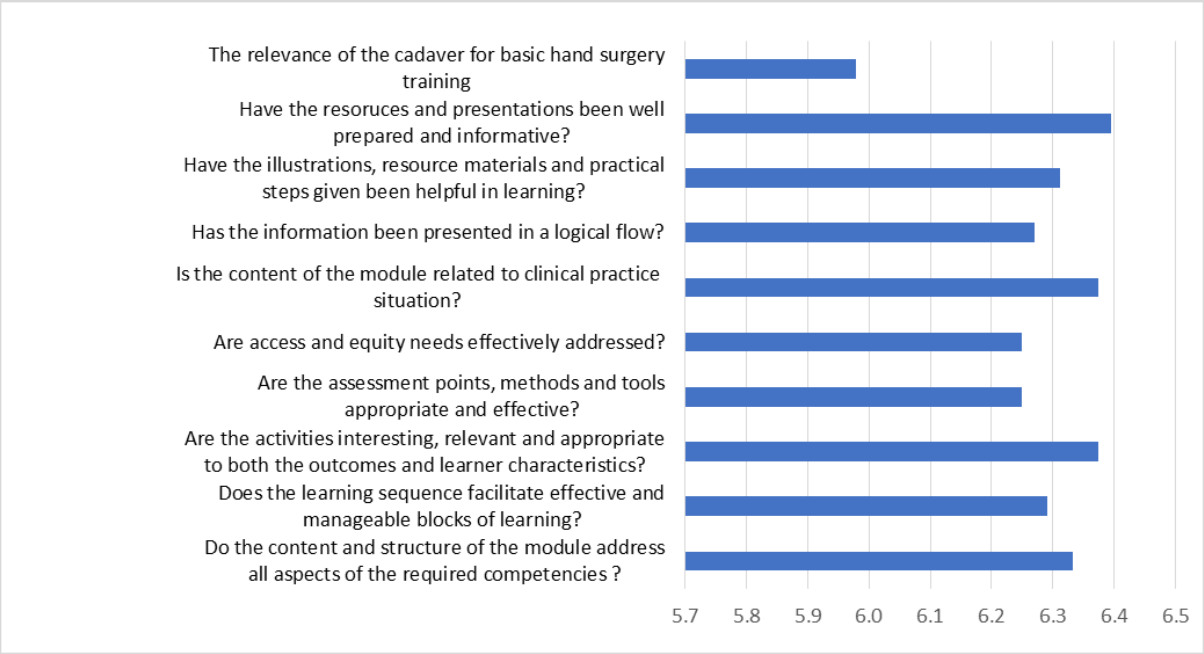

Figure 4: *Validity of the hand surgery training program*

Table 3: *Average scores for all 10 questions*

Count	10
Sum	63
Mean (Average)	6.3
Median	6.3
Mode	6.3, appeared 6 times
Largest	6.4
Smallest	6.0
Range	0.4
Geometric Mean	6.30
Standard Deviation	0.11
Variance	0.01
Sample Standard Deviation	0.11
Sample Variance	0.01

Table 4: *Summary*

SUMMARY	Count	Sum	Average	Variance
Does the content and structure of the module address all aspects of the required competencies?	48.0	304.0	6.3	0.7
Does the learning sequence facilitate effective and manageable blocks of learning?	48.0	302.0	6.3	0.7
Are the activities interesting, relevant, and appropriate to both the outcomes and learner characteristics?	48.0	306.0	6.4	0.5
Are the assessment points, methods, and tools appropriate and effective?	48.0	300.0	6.3	0.7
Are access and equity need effectively addressed?	48.0	300.0	6.3	1.0
Is the content of the module related to a clinical practice situation?	48.0	306.0	6.4	0.5
Has the information been presented in a logical flow?	48.0	301.0	6.3	0.8
Have the illustrations, resource materials and practical steps given been helpful in learning?	48.0	303.0	6.3	0.5
Have the resources and presentations been well prepared and informative?	48.0	307.0	6.4	0.5
The relevance of the cadaver for basic hand surgery training	48.0	286.0	6.0	1.2
Cronbach Alpha			0.94	

Conclusion

This design and development research has described the methodological approach to the use of the ADDIE model of instructional design to create a scientific, evidence-based and structured approach to creating a training skills program in hand surgery. The use of the cadaver model has proven to be useful and effective in the transfer of skills and is perceived to be authentic and effective by participants and faculty members as shown in this study. Further research of the use of this model and technique can be done in other domains of surgery to show acceptance and validity of training programs for skill acquisition in surgery.

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