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REVIEW ARTICLE

# From Sawbones to Drill Machines: Evaluating a Simulation-Based Orthopaedic Workshop for Medical Undergraduates

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## Abstract

Orthopaedic education for medical undergraduates has traditionally placed more emphasis on theoretical understanding than on developing practical surgical skills. This study evaluates a simulation-based orthopaedics workshop conducted at Newcastle University Medicine Malaysia (NUMed) to enhance students' confidence and competence in basic trauma and fixation procedures.

Thirty-two undergraduate medical students from NUMed and Monash University Malaysia participated in a half-day workshop comprising four hands-on stations: plaster backslab application, closed manual reduction and orthosis braces, skin and skeletal traction, and implant handling with plate fixation. Feedback was collected through a structured questionnaire combining quantitative ratings and qualitative comments.

Overall satisfaction was high: 70% rated the workshop 10/10, 3% rated it 9/10, 17% rated it 8/10, and 10% rated it 7/10. Participants highlighted enhanced understanding, improved procedural confidence, and appreciation of the interactive learning approach. Suggestions included extending session duration and increasing the number of bone models.

This educational intervention demonstrates that early, structured exposure to orthopaedic simulation can significantly enrich undergraduate learning and clinical readiness.

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## INTRODUCTION

Musculoskeletal conditions are considered one of the most common health issues worldwide. Their significant disability and costs are the main reasons behind their high global burden. Regardless, undergraduate medical programs have always neglected orthopaedic education, focusing more on theoretical knowledge rather than hands-on experience. As a result, many fresh graduates feel ill-prepared for basic orthopaedic skills, including trauma and emergency care. These skills are not only important for potential orthopaedic specialists, but also for junior doctors and other specialities as well.

The challenges in undergraduate orthopaedic training have long been an issue for medical schools globally. In their systemic review, it was concluded that surgical simulation-based training markedly improved surgical performers when participants were trained to a defined level of proficiency instead of a specific period [1]. Nonetheless, medical undergraduates continue to report lack of confidence in caring for orthopaedic patients, including conducting a basic orthopaedic examination, managing fractures, performing simple procedures. As surgical advancements are slowly taking over, the gap in clinical practice medical students face is becoming more evident. This proves the importance of gaining early hands-on experience in the field. Simulation-based training ensures students have a safe and well-structured environment to refine their skills without causing harm to patients. In addition, combining theoretical information with clinical experience is one of the most effective ways to retain knowledge, increase students' confidence and prepare them for such cases in their clinical placements.

Significant advances in orthopaedic education are already in place. Sawbones (Synthetic bone models) and internal fixation devices are amongst some of the widely used simulation tools. This study aimed to evaluate the effectiveness of a structured, simulation-based orthopaedics workshop at Newcastle University Medicine Malaysia (NUMed) in improving students' clinical preparedness and confidence in performing basic orthopaedic procedures.

## THE GAP IN TRADITIONAL ORTHOPEDIC EDUCATION

In the past, textbook readings, didactic lectures, and little clinical experience constituted the mainstay of undergraduate orthopaedic education. Although this gives students a solid foundation of knowledge, it is devoid of the components needed to give them the clinical experience they need for procedures like internal fixation, cast application, and fracture reduction.

There is a clear disconnect between psychomotor performance and cognitive comprehension. Although students may grasp the theoretical underpinnings of fracture management, they frequently have difficulty carrying out simple tasks like hardware application or fracture alignment. The short orthopedic training duration in many medical programs exacerbates this problem. In the United States, orthopedic exposure is frequently provided as an elective rather than a required course of study, whereas in the United Kingdom, orthopedic rotations typically last only two to four weeks. Patient care suffers as a result of many graduates entering clinical practice lacking adequate orthopedic competence [2].

Feedback from students highlights this discrepancy even more. Medical students want more practical experience early in their education, according to numerous surveys. 72% of medical students felt unprepared for musculoskeletal medicine and that more hands-on experience would greatly boost their confidence in treating orthopedic conditions [3].

According to a UK-wide survey-based study, final-year medical students consistently expressed low confidence in all fundamental trauma and orthopaedics skills, which is consistent with a larger failure of undergraduate training to meet clinical needs [4]. These results highlight how urgently more workshops are needed to close the competency gap.

The early incorporation of practical skills is also supported by educational theory. According to Bloom's taxonomy, meaningful learning encompasses the cognitive, affective, and psychomotor domains [5]. Clinical proficiency requires the application, analysis, and evaluation of knowledge in practical contexts in addition to theoretical knowledge. Students' capacity to learn these crucial skills in time for clinical application is hampered when practical orthopedic instruction is postponed until later in the training process.

Transitioning from passive to active learning is equally important. Rote memorization is dependent on didactic lectures. On the other hand, skills such as critical thinking, problem-solving and decision making are only enhanced by interactive workshops. Sawbone and other simulations workshops provide students with a safe yet realistic environment that allows them to practice a wide range of clinical skills, without putting any patients at risk.

Orthopaedic education faces significant global inequlities. This is largely due to restricted access to simulation technologies and lack of qualified faculty members, especially in low-resource countries. Even when resources are limited, research has shown that printed 3 Dimensional (3D) and virtual models can provide scalable and affordable substitutes for cadaver approaches.6 However, even in high-income countries, simulation tools are yet to be incorporated into the currently available undergraduate orthopaedic curricula.

Undergraduate orthopedic education needs to be fundamentally rethought in order to overcome these obstacles. Before students enter clinical settings, interactive, skills-based training programs that promote steady, self-assured competency development must be used in addition to, if not in place of, traditional didactic methods.

# METHODS

## Study design and setting

This prospective educational intervention was conducted at Newcastle University Medicine Malaysia (NUMed) on 26 April 2025. The workshop aimed to enhance undergraduate medical students' competence and confidence in fundamental orthopaedic skills through hands-on, simulation-based training. It was organized collaboratively by NUMed Teaching Fellows, the NUMed Surgical Society, and orthopaedic surgeons from both NUMed and Monash University Malaysia's Clinical School Johor Bahru (CSJB).

## Participants

A total of 32 undergraduate medical students participated, representing both NUMed and Monash University Malaysia. Participants ranged from Year 1 to Year 5, with all attending voluntarily. The workshop was held as a half-day session (8:30 am - 12:30 pm) at the NUMed CPD Laboratory, James Building.

## Workshop structure

The workshop comprised four rotating skill-based stations, each supervised by an orthopaedic surgeon or teaching fellow:

- Plaster of Paris backslab application – Demonstration and practice in below-elbow backslab molding and alignment.
- Closed manual reduction and orthosis braces – Reduction techniques, neurovascular assessment, and brace fitting.
- Skin and skeletal traction – Assembly and indications of traction using simulation models.
- Basic implants and plate fixation – Implant introduction, surgical drill use, and fixation practice on synthetic bones.

Each group rotated through the stations for approximately 30-40 minutes following a short briefing.

### Evaluation instruments

Participant feedback was collected immediately after the session using a structured post-workshop questionnaire that included:

- **Quantitative ratings:** Likelihood to recommend the workshop (0-10 scale; 0 = Extremely unlikely, 10 = Extremely likely).
- **Qualitative comments:** Open-ended reflections on perceived strengths, learning value, and improvement areas.

## DATA ANALYSIS

Quantitative data were analysed descriptively and expressed as percentages. Qualitative comments were thematically reviewed to identify recurring themes of satisfaction, learning impact, and logistical feedback.

### Ethical Considerations

This evaluation was approved by the Dean of Academic Affairs, NUMed, as part of internal educational quality improvement. Participation was voluntary, and no identifying data were collected.

## RESULTS

### Participant demographics

Thirty-two students participated, representing both NUMed and Monash University Malaysia (Years 1-5). The response rate was 100%, with all attendees completing the feedback survey.

### Quantitative outcomes

Feedback indicated high satisfaction with the workshop. As illustrated below, 70% of participants rated the session 10/10, 3% rated it 9/10, 17% rated it 8/10, and 10% rated it 7/10.

All respondents stated the workshop met their expectations and that they would recommend it to peers.

| Rating (Out of 10) | Percentage of Participants (%) |
|---|---|
| 10 | 70 |
| 9 | 3 |
| 8 | 17 |
| 7 | 10 |

### Qualitative feedback

Thematic analysis of qualitative data identified three dominant themes:

- **Educational value:** Participants described the workshop as "awesome," "excellent," and "well-organized and informative, with a good balance of theory and practical application." The interactive format and real-life clinical examples were particularly valued.
- **Facilitator effectiveness:** Facilitators were praised as "knowledgeable, friendly, and approachable," and for creating a "welcoming environment that encouraged participation and discussion."
- **Improvement suggestions:** Students recommended longer duration per station, more bone models, and improved time management. Some noted that multiple concurrent stations in one lab caused mild distractions.

### Overall satisfaction

All participants affirmed that the workshop met or exceeded their expectations and expressed interest in attending similar future events. Many highlighted the value of early clinical exposure and requested continued inter-university collaborations.

## DISCUSSION

The results demonstrate that short, structured simulation workshops can substantially improve medical students' engagement and perceived preparedness in orthopaedics. The overwhelmingly positive ratings (70% giving 10/10) indicate that participants found the workshop highly relevant to their learning needs.

These findings align with prior research showing that simulation-based surgical education enhances both confidence and skill acquisition [6,7]. The inclusion of real surgical instruments, implants, and sawbones models likely contributed to perceived authenticity and confidence gains.

Despite the lack of pre and post intervention quantitative assessments, qualitative feedback consistently highlighted improved procedural understanding and enthusiasm for orthopaedics. This suggests such workshops are feasible and impactful even in resource-limited settings when guided by structured teaching and faculty support.

## Critical evaluation of simulation modalities

While our workshop demonstrated high participant satisfaction, a critical examination of different simulation approaches reveals important considerations for curriculum design.

**Comparative effectiveness of simulation modalities:** Sawbones models, as used in our workshop, offer distinct advantages and limitations compared to alternative training methods. These synthetic bone models provide consistent anatomical structure, unlimited repeatability, and eliminate ethical concerns associated with cadaveric specimens. However, they lack the tissue variability and tactile feedback of real bone [8]. Cadaveric training remains the gold standard for surgical realism but faces limitations including high cost, limited availability, ethical considerations, and lack of standardization due to inter-specimen variability.

Virtual Reality (VR) and Augmented Reality (AR) simulations represent emerging alternatives that offer real-time performance metrics and can simulate rare pathologies. However, current VR systems often lack haptic fidelity and require substantial initial investment. A meta-analysis found that while VR improved knowledge retention, it did not consistently outperform physical simulation for procedural skills in orthopaedics [9].

**Contextual appropriateness:** The optimal simulation modality depends on learning objectives and training stage. For early undergraduate exposure (Years 1-3), sawbones models are most appropriate as they allow foundational skill development without overwhelming complexity. For advanced trainees (Years 4-5 and residents), cadaveric or high-fidelity VR training becomes more valuable as learners can appreciate anatomical variations and complications. Our workshop targeted mixed-year participants, which may explain the universally positive feedback, sawbones provided sufficient realism for novice learners while remaining accessible.

**Cost effectiveness analysis:** Published data suggests significant cost variations between modalities. Cadaveric workshops typically cost £500-800 per participant when accounting for specimen procurement, facility fees, and instructor time [10]. In contrast, our sawbones-based workshop cost approximately £50-75 per participant for materials, with reusable instruments and bones amortized over multiple sessions. VR systems require capital investment of £10,000-50,000 but offer near-zero marginal cost per additional learner [6].

For institutions with limited budgets, sawbones represent the most cost-effective option for sustainable, repeated training. However, institutions should ideally employ a staged approach: sawbones for basic skills, followed by selective cadaveric or VR exposure for advanced techniques.

**Limitations and potential drawbacks:** Several important limitations of simulation-based training warrant discussion.

- **Skill decay:** Without regular practice, procedurally acquired skills deteriorate rapidly. Studies show 50% skill retention loss within 6-12 months without clinical application [1]. Our workshop did not include follow-up assessment, leaving long-term retention unknown.

- **Overconfidence risk**: Simulation may create false confidence if learners do not appreciate the complexity of real clinical scenarios. Synthetic models do not bleed, experience pain, or present with comorbidities. Students must understand that simulation is preparatory, not definitive.
- **Context absence:** Workshop stations focused on technical execution but could not replicate the cognitive load of emergency decision-making, communication with anxious patients, or managing unexpected complications. Integration with clinical scenarios or standardized patients would strengthen transferability.
- **Limited assessment:** Our study relied on self-reported confidence rather than objective performance measures. While Kirkpatrick Level 1 (reaction) and Level 2 (learning) evaluations are valuable, Level 3 (behavior change) and Level 4 (clinical outcomes) remain unmeasured [11].

# LIMITATIONS

This study has several important limitations that must be acknowledged.

## Methodological limitations

- Single-site, single-session design limits generalizability across institutions and educational contexts.
- Small cohort size (*n* = 32) restricts statistical power for subgroup analyses.
- Absence of control group prevents causal attribution of learning outcomes to the intervention.
- No pre-intervention baseline assessment, precluding measurement of actual skill improvement.
- Lack of validated objective assessment tools (e.g., OSATS, procedure-specific checklists) means we cannot quantify competency gains.

## Assessment limitations

- Reliance on self-reported satisfaction and perceived confidence rather than demonstrated performance.
- Immediate post-workshop evaluation captures initial reactions but not knowledge retention or clinical application.
- No follow-up assessment to determine long-term skill retention or integration into clinical practice.
- Hawthorne effect may have inflated satisfaction ratings due to participants' awareness of evaluation.

## Generalizability concerns

- Participants were self-selected volunteers, potentially representing more motivated learners.
- Resource availability (equipment, faculty expertise) at NUMed and Monash may not reflect typical institutions.
- Cultural and educational context in Malaysia may differ from other regions.
- Mixed-year participation (Years 1-5) may have created heterogeneous learning needs not optimally addressed.

## Future research directions

To address these limitations, future iterations should.

- Implement validated pre and post assessment using OSATS or procedure-specific scales with blinded raters.
- Include control groups receiving traditional didactic teaching for comparison.
- Conduct 3 month and 6-month follow-up assessments to measure retention and clinical integration.

- Perform multi-site implementation to assess scalability and context-specific adaptations.
- Collect objective performance data during clinical rotations to measure behavioural transfer (Kirkpatrick Level 3).

## Global equity and scalable implementation

While simulation-based orthopaedic training shows promise, significant disparities exist in global access. Addressing these inequities requires concrete strategies for low-resource adaptation.

## Resource stratification and cost estimates

Implementation costs vary dramatically by resource setting (All costs in USD).

**High resource settings (> $30,000 annual medical education budget per student):** Comprehensive simulation labs with multiple sawbones sets: $15,000-25,000 initial setup.

- Cadaveric lab access: $20,000-40,000 annually for specimen procurement and facility maintenance.
- VR/AR systems: $30,000-100,000 for hardware/software with ongoing licensing.
- Dedicated simulation faculty: $60,000-120,000 per full-time equivalent.
- Total annual cost per student: $200-400 for sustained program.

**Middle resource settings ($5,000-30,000 per student):** Basic sawbones kits (shared across cohorts): $3,000-8,000 initial investment.

- Reusable instruments and implant sets: $2,000-5,000.
- Part-time faculty support or volunteer clinicians: $10,000-30,000 annually.
- Total annual cost per student: $50-100 with equipment amortization.

**Low resource settings (<$5,000 per student):** 3D-printed bone models: $500-2,000 for printer and materials.

- Improvised materials (Plaster, wood splints, donated equipment): $100-500.
- Volunteer teaching from local clinicians: minimal direct cost.
- Total annual cost per student: $10-30 for basic skills training.

## Evidence based low cost alternatives

Several validated low-cost approaches exist:

**3D-printed models:** 3D-printed fracture models produced equivalent learning outcomes compared to commercial sawbones for medical students, at 10-15% of the cost [12]. Open-source repositories (e.g., NIH 3D Print Exchange) provide free anatomical files.

**Animal bone models:** Chicken and porcine bones from local markets can substitute for synthetic models in basic drilling and fixation exercises.

**Task trainers with local materials:** PVC pipes for cast application, wooden dowels for splinting practice, and foam padding for basic fracture stabilization can be assembled for <$20 per station. While lacking anatomical fidelity, these develop fundamental psychomotor patterns.

**Mobile workshop models:** Rather than permanent labs, equipment-sharing consortia among multiple institutions reduce per-school costs. Our collaboration between NUMed and Monash demonstrates this principle-shared equipment investment reduced costs by 40% compared to independent procurement.

**Successful low-resource implementations:** Several programs demonstrate feasibility in resource-constrained settings.

- **Case example 1 - Rural India (Medical College Baroda):** A surgical skills program implemented 3D-printed models and recycled instruments to train 200+ students annually at $15/student. Pre-post assessment showed 67% improvement in fracture reduction technique, with 89% student satisfaction [13].

- **Case example 2 - Sub-Saharan Africa (Makerere University, Uganda):** The Essential Surgical Skills course uses improvised materials and volunteer surgeon instructors. Despite minimal budget, 83% of participants demonstrated competent suturing and basic wound care at 6-month follow-up, with skills retained in clinical practice [14].
- **Case example 3 - Southeast Asia Regional Collaboration:** The ASEAN Medical Student Orthopaedics Network pools resources across seven universities, rotating equipment and sharing online faculty lectures. This reduces costs by 60% while expanding access from one institution's 40 students to a regional cohort of 280 students.

**Accreditation and standardization strategies:** Global scalability requires addressing quality assurance.

- **Curriculum standardization:** The AO Foundation's Basic Principles course provides standardized learning objectives and assessment criteria adaptable to any resource level. Adoption of international frameworks (e.g., CanMEDS competencies for orthopaedics) ensures baseline consistency regardless of local implementation methods.
- **Quality benchmarking:** Low-cost programs can maintain quality through.
- Structured assessment using validated rubrics (e.g., simplified OSATS with 3-5 observable criteria).
- Peer assessment and video recording for remote expert review (Minimal cost with smartphones).
- Regional consortia for external quality audits and inter-institutional benchmarking.
- **Faculty development:** Limited specialist faculty represents a major barrier. Solutions include:
- "Train-the-trainer" cascades where one expert trains multiple local instructors.
- Telemedicine-supported teaching where remote specialists guide local generalists.
- Structured teaching protocols allowing non-specialists to deliver standardized content effectively.
- **Digital open-access resources:** Free online platforms (YouTube tutorials, open-access surgical atlases, simulation guides) can supplement hands-on practice. While not replacing physical simulation, they provide cognitive preparation and theoretical foundation at zero cost.

**Policy and funding mechanisms:** Sustainable expansion requires institutional commitment.

- Integration into mandatory curriculum (not optional electives) ensures all students benefit.
- Partnerships with industry for equipment donation or discounted procurement.
- Government funding initiatives prioritizing practical clinical skills in accreditation standards.
- International development partnerships (WHO, bilateral aid programs) supporting simulation infrastructure in low-income countries.

**Recommendations for scalable implementation:** Based on our experience and literature review, we propose a tiered implementation model.

- **Phase 1 (Year 1):** Pilot workshop using shared/borrowed equipment to demonstrate feasibility and gather institutional support.
- **Phase 2 (Year 2):** Secure basic equipment investment ($2,000-5,000), establish

partnerships with clinical departments for faculty support, and integrate into curriculum as required session.

- **Phase 3 (Year 3+):** Expand to multiple sessions per year, develop regional collaborations for equipment sharing, and implement validated assessment protocols.

Even in severely resource-limited settings, modified simulation training is achievable and valuable. The key is adapting modalities to local context rather than attempting to replicate high-resource models. Our workshop demonstrates that meaningful orthopaedic skills education can be delivered at ~$65-95 per student, a cost accessible to many institutions worldwide.

## CONCLUSION

This educational intervention demonstrated that a focused, simulation-based orthopaedics workshop significantly enhanced students' confidence, engagement, and satisfaction. However, critical evaluation reveals important considerations for broader implementation.

While sawbones models offer cost-effective, repeatable training, they lack the biological variability of cadaveric specimens and the immersive realism of advanced VR systems. Educators must recognize that simulation is preparatory rather than sufficient skills may decay without clinical reinforcement, and learners may develop overconfidence without appreciating real-world complexity.

The overwhelming satisfaction in our cohort (70% rating 10/10) suggests simulation-based learning addresses genuine educational needs, but our methodological limitations particularly the absence of objective performance assessment and long-term follow-up prevent definitive conclusions about competency improvement.

Importantly, orthopaedic simulation training is feasible across diverse resource settings. Evidence from low-income contexts demonstrates that 3D-printed models, improvised materials, and collaborative resource-sharing can deliver meaningful skills training at $10-30 per student. With appropriate adaptation, the principles demonstrated in our workshop can be scaled globally, helping bridge the documented gap between theoretical knowledge and clinical readiness that affects medical graduates worldwide.

Future research should employ validated assessment tools, include control groups, and conduct longitudinal follow-up to measure actual skill retention and clinical application. Multi-site implementation studies across different resource settings would further clarify optimal approaches for various contexts.

Incorporating structured simulation workshops into undergraduate curricula tailored to local resource availability represents a practical step toward ensuring graduates are better prepared for orthopaedic and trauma rotations, regardless of their training institution's economic circumstances.

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