Augmented Reality's Role in Surgical Training Mastery: A Bridge to Sustainable Development Goals in Line with Kirkpatrick's Pyramid

Authors: Ali Waleed Khalid, **Zaina Aloul**, Mohammed ElBahnasawi, Matthew Haris Harris, Samuel Colman, David Rawaf, Luqman A Tenang.

Introduction:

Novel Augmented Reality-based surgical simulator offers immersion and objective performance capture in surgical training, yet its thorough evaluation encompassing Kirkpatrick's pyramid levels is essential. In response to transformative shifts in post-graduate surgical education driven by factors such as the COVID-19 pandemic and the imperative for patient safety, augmented reality (AR) high-fidelity laparoscopic simulators have emerged as a promising solution. These simulators, exemplified by INOVUS Medical Ltd's Augmented Reality-based laparoscopic simulator LapAR, offer objective and subjective validation of surgical training. Traditional methods relied on patient-based practice, which was costly and less effective. In light of this, virtual reality and simulations gained traction as supplementary tools. This study aims to comprehensively evaluate the novel AR-based surgical simulator across Kirkpatrick's pyramid levels, aiming to reformulate educational paradigms and align with Sustainable Development Goals (SDGs), ultimately enhancing surgical training effectiveness.

Methodology:

a multi-faceted approach encompassing the following studies:

Self-Confident Assessment (Level 1- Reaction):

We employed a pre-and-post-training survey utilizing Likert scaling as well as qualitative interview analysis of the participants experience measuring self confidence scores.

Pilot Study (Level 2 - Learning):

A pilot study (n=15) was conducted to examine junior trainees' performance in appendectomies and vaginal cuff closures focusing on completion time and distance travelled metrics.

Systematic review (Level 3-Behaviour): Evaluation of existing literature to measure translatability and efficacy of AR/VR-based surgical training to calculate mathematically the translatability of acquired surgical skills in clinical practice :Table 1

Health Economics Review (Level 4 - Results):

BMJ-Peer reviewed health economics study focused on organisational benefits of AR-base surgical training to estimate savings per patient per year per hospitals in the UK and The USA.

Results:

Self-Confidence Assessment (Level 1- Reaction)

The self-confidence scores improved, with a mean improvement of 3.82 (Likert, p=0.018). In the interview analysis, it was found that the training method was ideal to the start of surgical training. Participants suggested making it mandatory, and they also wished for an extended access period to the training kit.

Pilot Study (Level 2 - Learning):

Statistically significant reduction in both completion time and distance travelled with P-values ($p<0.001$)and ($p<0.05$) respectively, observed which underscore the skill advancement facilitated by AR training

Level 3- Behaviour: Translatability mean value across 4 randomised control trials of 49.3 % that was statistically significant with $P<0.05$.

Level 4 - Results : organisational benefits.

Appendicectomy chosen as example : Increased efficiency , Reduced complication rates , Improved surgical skill

Savings per patient: £79-455 ($90-517)10-100%

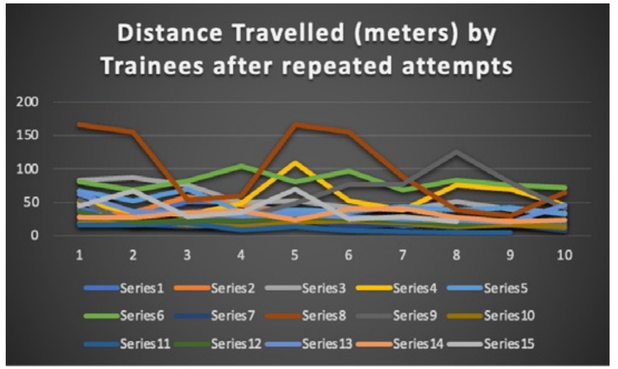
translation of time saving: 6093 US hospitals

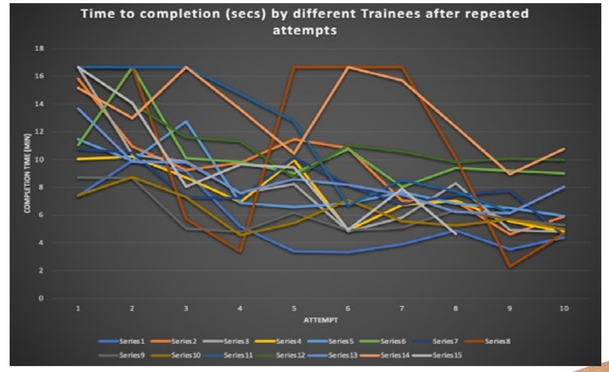
1st year savings (including costs)

@10% translation:

£777,579 ($4,334,984).

Study refrence	Study Descriptions	Translatability Figure (%)
Xiaoli L, Zhiyuan Z, Yiming Z, et al. (2021)	Patients with balance disorders underwent virtual reality-based balance training compared to conventional training, resulting in a 20% improvement in balance and gait parameters.	20%
Vasileios P, Ioannis T, Konstantinos K, et al. (2022)	Laparoscopic surgery trainees underwent virtual reality simulator training, leading to a 78.63% improvement in laparoscopic surgical skills.	78.63%
Piotr K, Izabela K, Katarzyna K, et al. (2021)	Patients with chronic lower back pain showed a 75.33% improvement in pain reduction and functional outcomes through mixed reality technology.	75.33%
Panait,Hogle Fowler et al., (2011)	Surgical residents completing an advanced laparoscopic skills curriculum exhibited a 23.2% improvement in laparoscopic skills.	23.2%





Conclusion:

The novel Augmented Reality-based surgical simulator showcased favourable outcomes across Levels 1 to 4 of Kirkpatrick's pyramid.

Strong evidence base for faster skill acquisition, confidence, surgical skill and safety. Preferred and more effective at providing clinically translatable & scalable cost-effective laparoscopic training.

The alignment with SDGs underscores the broader societal implications and reinforces the substantial impact of this research.



Acknowledgements:

We are interns/executives within Inovus Medical, which has provided support but not funding for this study. We have sought to avoid over-mentioning products or pushing sales. Our intention is to increase awarenesss of alternative augmented reality training options to drive surgical training away from the patient's bedside.

We extend gratitude and thanks to SAGES for allowing us to present our findings.

Inovus Medical is an eligible company and is an accredited provider for CPD/CME points for surgical training.