Original Research Article

Feasibility and Effectiveness of a Simulation-Based Flipped Classroom for Teaching Surgical Suturing Skills in a Low-Resource Setting

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Kirya Musa[1,2], Josephine Namugenyi[3], Charity Mutesi[4], Kyegombe Willy[2], Paul Otim[2], Fred Kirya[2] and Wilfred Arubaku[5]

Abstract

Background: Surgical skills training in low-resource settings, such as Uganda, often relies on traditional didactic methods with limited hands-on experience, resulting in competence gaps among graduates. The flipped classroom model, a student-centered approach where foundational content is learned outside the classroom, and in-class time is used for active practice, offers a promising alternative, particularly for skill-based instruction. This study explored the feasibility and effectiveness of a simulation-based flipped classroom in teaching surgical suturing skills to third-year medical students at Soroti University.

Methods: This was a quasi-experimental study in which 55 third-year students participated in a flipped learning module that incorporated pre-class materials (videos, readings, and suturing kits) and in-class simulations using porcine skin. Outcomes were measured through pre-, post-, and 3-month follow-up multiple-choice tests for knowledge, as well as Objective Structured Assessment of Technical Skills (OSATS) scores for skill performance.

Results: Post-test knowledge scores showed a marked improvement compared to pre-test scores (mean gain = 39.9, $P < 0.0001$), with a normalization gain of 70%. In the OSATS observation checklist, most students were rated as competent (49%) or excellent (33%) immediately after training. At 3 months, knowledge retention was 88% despite a statistically significant decline ($P < 0.0001$). Interestingly, OSATS performance scores improved at 3-month follow-up (+3 points, $P = 0.0011$), suggesting procedural consolidation over time.

Conclusion: The flipped simulation model appears feasible and may be effective in enhancing early surgical skill, and knowledge acquisition and retention among medical students in low-resource settings. It fosters experiential learning and improves both cognitive and psychomotor competence. These findings support the potential for expansion to other skills and subsequent integration of this approach into undergraduate surgical training curricula in LMICs.

Clinical trial number: Not applicable.

Keywords

Flipped classroom, surgical suturing, simulation-based medical education, low-resource settings, OSATS, skill retention

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Background

For decades, traditional medical education has been predominantly teacher-centered, with learners passively absorbing knowledge from experts.[1] This model is particularly evident in surgical training, where the "see one, do one, teach one" philosophy still prevails.[2,3] However, with the dynamic needs of twenty-first-century learners and the evolving demands of clinical practice, this passive learning model is increasingly inadequate.[4,5]

Contemporary surgical education requires clinicians who not only possess theoretical knowledge but are also competent and confident in performing practical procedures. Suturing, a fundamental surgical skill, is essential for safe

[1] East Africa Faimer Regional Institute (EAFRI), Kampala, Uganda
[2] Department of Surgery, School of Health Sciences, Soroti University, Soroti, Uganda
[3] Department of Surgery, Soroti Regional Referral Hospital, Soroti, Uganda
[4] Makerere College of Health Sciences, School of Public Health, Kampala, Uganda
[5] Department of Dental Surgery, Faculty of Medicine, Mbarara University of Science and Technology, Mbarara, Uganda

Corresponding Author:
Kirya Musa, Department of Surgery, School of Health Sciences, Soroti University, P.O. Box 211 Soroti, Uganda.
Email: kmusa478@gmail.com

and effective patient care.[6] Unfortunately, in many low-resource settings, surgical skill acquisition remains unstructured and largely dependent on opportunistic observation rather than deliberate training.[7,8] This leads to inconsistent skill acquisition among medical students, most of whom are expected to perform major surgical procedures shortly after graduation.

In response, innovative approaches such as the simulation-based flipped classroom (SBFC) model are being adopted.[9,10] In this learner-centered model, foundational knowledge is acquired outside the classroom through videos, readings, or even practice, while classroom time is reserved for active, hands-on learning, and application of skills.[11,12] This approach encourages critical thinking, self-direction, and retention of complex procedural skills.[13]

Several systematic reviews have shown that flipped classrooms improve knowledge and student satisfaction in health professions education.[14,15] A recent meta-analysis confirmed that flipped classrooms significantly enhance knowledge acquisition compared to traditional lectures across multiple health disciplines.[16] Specific pilot studies in skill-based domains, such as laparoscopic suturing and cardiopulmonary resuscitation, have demonstrated superior performance outcomes with simulation-based flipped approaches compared to conventional teaching[9,10] In a recent evidence from Asia, Banos et al found out that hybrid video-simulation models when used to flip the class, improved both performance and self-efficacy in clinical skills training.[17]

While many published studies paint a promising picture about flipped learning and simulation, majority of them come from high-income contexts, with limited evidence from sub-Saharan Africa. Importantly, few studies assess both the feasibility of implementing SBFC in resource-constrained settings and the medium-term retention of knowledge and skills.[18]

In Uganda, surgical skills training is still mostly delivered through didactic lectures or unstructured clinical exposure.[19] This raises concerns about the adequacy of current training methods and their impact on clinical competence.

Given that general practitioners in Uganda often provide frontline surgical care, ensuring competency in basic surgical procedures such as suturing is crucial.[20] Yet, the most effective and context-appropriate instructional method remains unclear. This study was therefore conducted to evaluate the feasibility and effectiveness of a SBFC in teaching surgical suturing skills to third-year medical students in a resource-constrained academic setting.

Methods

This Quasi-experimental study was conducted at Soroti University's Department of Surgery to explore the feasibility of a SBFC for training third-year medical students in surgical suturing skills. The University, a public institution located in Eastern Uganda, has been training medical students since 2019. The study was conducted over 1 week, and with a follow-up exercise 3 months later. It targeted 70 Year III students in the second semester of their junior clerkship rotations. No formal sample size or power calculation was performed. The primary objective of the study was to assess feasibility and educational impact, and therefore all eligible Year III medical students available during the study period were included. Of the 70 Year III medical students, 55 enrolled during the study period, were considered eligible. Inclusion criteria were, completion of preclinical training. Exclusion criteria for analysis included students with previous clinical professional training and or practice (eg, nursing or clinical officer backgrounds), as such prior exposure could introduce bias in assessing the effectiveness of the intervention. These students were allowed to participate in the training sessions for educational purposes but were excluded from the outcome analysis.

Before the intervention, students were given a 30-question multiple-choice (MCQ) quiz to assess baseline knowledge in suturing, gloving, local anesthesia, and wound closure techniques. Students were oriented about the flipped classroom approach and provided with learning materials, including 5-8-min instructional videos (2 per session), 2 truncated textbook chapters, and 1 journal article, all shared via WhatsApp and email. Additionally, each student received a practice kit with suturing instruments and a banana for home practice.

The in-class component was conducted over 3 days using pigskin in the skills lab. Each day began with a review of preclass material, followed by a live demonstration of the surgical techniques, captured in real-time by a moto G84 video camera, then cast through an overhead projector to the class. Students were paired and rotated between roles as surgeon and assistant during supervised hands-on sessions. Instructors facilitated these sessions using guiding questions to stimulate discussion and correct misconceptions. At the end of each day, key learning points were summarized, and post-class tasks were assigned.

Following the training, students repeated the MCQ quiz (post-test) and underwent practical skill assessment using the Objective Structured Assessment of Technical Skills (OSATS) tool.[21] OSATS evaluates performance across seven items on a 5-point Likert scale, with a maximum score of 35. Three months later, both the MCQ and OSATS assessments were repeated to evaluate retention of knowledge and skills. Students were randomly selected for assessment, switching roles during evaluation to ensure each demonstrated their abilities.

Data were entered in Excel and analyzed using STATA. For knowledge and skill acquisition, paired t-tests and descriptive statistics were used. Retention was measured by comparing post-intervention and 3-month follow-up mean scores. Ethical approval was obtained from Mbarara University of Science and Technology under the registration number: **MUST-2024-175**. Administrative clearance was sought and granted from Soroti University. All participants gave prior written informed consent before enrollment into the study and at the 3-month follow up. Confidentiality was maintained throughout the study. The suturing kits used were sterile and safe, posing no risk of infection to the students.

The reporting of this study conforms to the SQUIRE-EDU (Standards for Quality Improvement Reporting Excellence in Education) guideline.[22] A completed checklist is available as Supplementary File 1.

Results

Participant Demographics

We enrolled 55 students who participated in both the pre- and post-test. Most participants were Male (69%). They were all

year III medical students with an age range from 22 to 36 years. There were 5 facilitators, 4 males and 1 female, with at least 3 and 4 years of teaching and clinical experience, respectively, at the level of a surgeon.

At the 3-month follow-up data collection, we had 39 participants (26 male and 13 female), representing a 27% decline from the original participant number.

Comparison of Pre- and Post-Test Scores for Knowledge of Technical Skills

As shown in Table 1, our study found that the pre-test MCQ scores were poor, with the mean score way below average, at 41%. The post-test scores, however, were significantly higher than the pre-test scores ($t = 21(54)$, $P < 0.0001$). There was no statistically significant variation in pre- and post-test scores across age or gender at analysis of Variance.

Normalization Gain 70%

Almost half of the participants were competent (49%), while 33% achieved an excellent rating (Table 2). The distribution indicates that nearly 82% of the participants were rated as either competent or above, suggesting an overall positive performance outcome in the assessment

Comparison of Post-Test and Follow-up Scores at Three (3) Months for Knowledge of Technical Skill Assessment

In Table 3, our findings also showed a statistically significant decline in knowledge of technical skill by 9.9% between the post-test and at 3-month follow-up assessments ($t = 7.1(38)$, $P < 0.0001$). At the 3-month follow-up, 39 of the original 55 participants completed assessments, representing a 27% loss to follow-up.

To the contrary, there was a statistically significant improvement in the OSATS scores at 3 months after the intervention (Table 4). There was a mean improvement by 3 score points ($P < 0.0011$).

Discussion

The flipped classroom is an innovative learning approach that has been noted to promote student participation in learning activities.[23] By flipping the classroom, educators can create a more student-centered learning environment, where learners engage with foundational material at their own pace, and class time is dedicated to more interactive and immersive activities.[12] Typically, this involves providing students with digital resources such as videos, presentations, and selected literature to review before class, allowing for a more efficient use of face-to-face time.[24]

Our study, however, took a novel approach to the flipped classroom model by incorporating out-of-class hands-on practice into the learning process. Students were provided with surgical suturing sets and practice materials to use at home, enabling them to watch instructional videos and practice suturing techniques before attending simulation sessions. This innovative approach allowed students to develop foundational skills in a low-stakes environment, where they could experiment, make mistakes, and learn from them without the pressure of being in a high-fidelity simulation setting. By integrating hands-on practice into the flipped classroom, our study aimed to enhance the acquisition of technical skills in surgical suturing and to explore the potential impact of this approach in medical education.

The present study demonstrated that the flipped simulation approach significantly improved students' knowledge of technical skills in surgical suturing. The significant gain in students' knowledge of technical skills post-intervention as seen in Table 1 suggests that the flipped simulation model may enhance conceptual understanding. This finding aligns with previous studies demonstrating that flipped classrooms allow students to engage with theoretical material in advance, enabling deeper learning during hands-on sessions.[10,15,25] The observed normalized gain of 70%, which lies at the boundary between excellent and moderate categorization, confirms a meaningful educational effect and supports the growing evidence on flipped learning effectiveness in medical education, especially in procedural training contexts.[26,27] The normalized gain index of this category for junior clerks who had just been introduced to surgical skill training further emphasizes the effectiveness of this approach in technical skill training. Promising normalization indices have been found in other studies, although lower than the present study.[28,29]

The finding that most students reached the "competent" category of performance on the OSATS scale is especially notable given the resource-constrained setting of Soroti University, where access to simulation labs, surgical mentors, and consumable materials is limited. In many Ugandan and similar African institutions, hands-on surgical skills are often learned opportunistically during clinical rotations, with minimal structured instruction early in training.[7,30] It is even more interesting that 33% of these students scored in the excellent category, clearly indicating that even early-year medical students, when properly guided and given active practice opportunities, can reach clinically relevant skill levels. By introducing suturing skills through a flipped simulation model early in the clerkship phase, this study challenges the conventional sequencing of skills training.[31] Early structured exposure not only allowed learners to gain confidence but also ensured a more equitable and standardized opportunity for skill development across the class. This supports growing calls in global medical education to "front-load" essential procedural skills as part of competency-based training models.[5,32] The combination of flipped content delivery and simulation likely reinforced both cognitive and psychomotor domains, thereby accelerating competency acquisition and therefore yielding the above two positive outcomes. This is consistent with Reznick et al's (1997) findings that structured simulation with formative feedback, as is in flipped learning, significantly boosts technical performance.[21] It is further reinforced by another interesting study by Sedrakyan, which highlights the significant improvement in students' conceptual model understanding and validation capabilities when using feedback-enabled simulations.[33]

The finding that knowledge retention was 88% after 3 months indicates a relatively low level of knowledge decay,

Table 1. Comparison of Pre- and Post-Test (MCQ) Scores Assessing Baseline and Immediate Post-Intervention Knowledge of Suturing Techniques.

Score	Mean	SD	Mean Difference	95% CI	t (df)	P-value
Pre-test	41.42					
Post-test	81.33					
Difference (post-pre)	39.91	13.85	39.91	36-44	21(54)	<0.0001

Normalization gain 70%.
Results analyzed using paired t-test, n = 55.

which is encouraging in procedural learning. This level of knowledge retention is supported by many other studies that have demonstrated the high level of retention in a flipped classroom.[34,35]

However, one of the most striking findings from this study was the divergent trend between cognitive knowledge and technical performance at the 3-month follow-up (Tables 3 and 4). Specifically, while the mean knowledge score dropped significantly from 81.26 to 71.31 ($P < 0.0001$), indicating some decay in declarative knowledge**,** the OSATS score improved significantly, rising from 27.51 to 30.51 ($P = 0.0011$). This paradox challenges the assumption that technical performance is tightly bound to explicit knowledge, especially over time. We suggest several plausible explanations for this observation. The observed improvement in OSATS scores may reflect the proceduralization of skills: a process through which learners move from conscious, knowledge-driven execution to automatic, fluid performance through practice and repetition. While explicit technical knowledge may wane, implicit memory and motor learning pathways often persist and even strengthen over time.[36] This is consistent with motor learning theory,[37] which distinguishes between declarative knowledge (knowing how a knot is tied) and procedural memory (being able to tie it effortlessly under pressure). Another possibility is that the 3-month improvement reflects the benefits of delayed consolidation, where students reflect on and mentally rehearse procedures even without structured re-exposure. Prior research in surgical education has suggested that mental practice, even in low-resource contexts, can enhance skill retention and even improve performance over time.[38] It is also likely that the assessment tools measure different constructs**.** The post-test focused on knowledge of technical skills; conceptual and procedural understanding: while OSATS evaluates hands-on performance in real-time. As students practice or engage in clinical tasks during rotations, they may reinforce performance through muscle memory or contextual learning, even if theoretical knowledge fades. This is highly likely because immediately after the intervention, students were sent for community-based education where they could have chanced several practice opportunities. This divergence is particularly relevant in low-resource settings like Soroti University, where continuous access to learning materials is limited, but clinical exposure and peer learning may serve as informal reinforcement mechanisms.

It should also be noted, however, that attrition of 27% at follow-up may have introduced bias into the retention findings, as those who remained in the study could have differed in motivation or clinical exposure from those lost to follow-up.

For institutions in low- and middle-income countries, especially in rural or under-resourced regions, the flipped simulation model offers a pragmatic and scalable solution to overcome faculty shortages, simulation space constraints, and uneven clinical exposure. Delivering theoretical content via pre-class videos or reading allows educators to maximize scarce simulation time for supervised practice, making this model both time- and cost-effective. Moreover, this study provides proof of concept that early, structured skill acquisition is feasible even in resource-limited environments and may improve students' preparedness for clinical clerkships. It provides a framework for other Ugandan and regional universities to consider the early integration of procedural skills into their early clinical years.

It is however, important to note that, whereas all eligible students participated in the study, no sample size or power calculation was performed, and therefore the robustness of the effectiveness outcomes is limited. These results should therefore be interpreted as preliminary evidence, warranting further investigation in larger, adequately powered multicenter studies.

Table 2. Distribution of Participant Performance Scores on the Objective Structured Assessment of Technical Skills (OSATS) Immediately After the Simulation-Based Flipped Classroom Intervention (n = 39).

Category/Range	Frequency (n = 39)	Percentage (%)
Unsatisfactory (<18)	0	0
Borderline (18-24)	7	18
Competent (25-29)	19	49
Excellent (30-35)	13	33

Conclusion and Recommendations

This quasi-experimental study explored the impact of a SBFC approach on the acquisition of surgical suturing skills among third-year medical students in a low-resource setting. The findings demonstrated a statistically significant improvement in both knowledge and technical performance following the intervention, with large effect sizes in pre- and post-test scores. It also demonstrated the excellent intermediate-term retention of technical knowledge and improvement in procedural performance. These results suggest that the SBFC model is feasible and shows promise in enhancing procedural competence within the constraints of

Table 3. Comparison of Knowledge Retention as Measured by MCQ Scores at Immediate post-Test and 3-Month Follow-up among (n = 39).

Score	Mean	SD	Mean Difference	95% CI	t (df)	P-value
Follow-up test	71.31					
Post-test	81.26					
Difference (follow-up-post)	−9.9	1.4	−9.9	−12–7.1	−7.1(38)	<0.0001

Retention rate **88%**.
Results analyzed using paired t-test.

Table 4. Comparison of the OSSAT Scores Immediately After the Intervention and at 3-Month Follow-up.

Score	Mean	SD	Mean Difference	95% CI	t (df)	P-value
OSSAT at 3 months	30.51					
OSSAT after intervention	27.51					
Difference (after-before)	3	0.85	3	28-32	3.5 (38)	0.0011

limited resources, though further comparative studies are required to confirm effectiveness.

Recommendations

Scale and Integrate the SBFC Model: Expand its use to other procedural skills and incorporate it longitudinally into the surgical curriculum to promote continuity and competence across the clinical years.

Standardize Teaching and Feedback: Develop uniform instructional videos and clear performance rubrics to reduce variation across faculty members and ensure consistency in teaching and assessment.

Promote Active Engagement with Pre-Class Materials. Use short quizzes, reflection prompts, or guided worksheets to encourage thorough engagement with video content before simulation sessions.

Schedule Regular Formative Assessments for Skills Retention Since there was a modest decline in scores at three months, structured periodic assessments should be incorporated to reinforce retention.

Study limitations

Single-Institution Scope: The study was conducted in one medical school, which may limit the generalizability of the findings to other settings with different resources, student demographics, or curricular structures.

Observer and Performance Bias: The presence of facilitators during simulation sessions may have influenced students' performance due to the Hawthorne effect. Additionally, assessments of technical skills may carry subjective elements despite efforts to standardize evaluation.

Thirdly, there was a 27% loss to follow-up at 3 months, which may have influenced the observed retention outcomes. This attrition limits the certainty of the retention findings and underscores the need for strategies to minimize loss in future studies

Finally, the study did not include a formal sample size or power calculation. While we included all eligible students to maximize participation, the lack of a power estimation limits the ability to fully assess the robustness of the observed effectiveness outcomes.

Suggestions for Further Study

Multi-Center Studies: Future research should replicate this intervention across multiple institutions to assess external validity and determine if similar outcomes can be achieved in diverse educational and cultural contexts.

Longitudinal Follow-Up: Studies that track students over time—into clinical rotations or internship—would help evaluate the durability and clinical transfer of skills learned through the SBFC approach.

Comparative Studies: Research comparing the SBFC model with traditional teaching methods or other blended learning approaches could further clarify its relative effectiveness in procedural skills training.

Cost-Effectiveness Analysis: Exploring the cost implications of implementing the SBFC at scale, especially in low-resource environments, would be useful for institutional decision-makers and policy planning.

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ORCID iDs

Kirya Musa https://orcid.org/0000-0001-5181-3800
Josephine Namugenyi https://orcid.org/0009-0002-6826-0901
Charity Mutesi https://orcid.org/0009-0003-5986-2211
Kyegombe Willy https://orcid.org/0000-0001-9913-7725
Wilfred Arubaku https://orcid.org/0000-0002-9415-2544

Ethical Approval

Ethical approval was sought and granted by Mbarara University Of Science and Technology under the registration number: **MUST-2024-175**.

All participants provided informed consent before taking part in the study. All study procedures were conducted in accordance with the Helsinki Declaration.

Consent for Publication

Not applicable.

Authors' Contributions

M.K. Developed the research proposal and spearheaded data collection and writing of the final book.
A. W. Faculty supervisor offered corrections and guidance from time to time until the final manuscript.
N. J. Participated in data collection, monitoring and report writing.
O. P. Participated in the report writing and data collection.
C.M. analyzed the data and participated in the writing of the final book.
K. W. Participated in proposal and manuscript writing.
K.F. Guided from time to time and also participated in the instruction process.

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Availability of Data and Materials

The data set and thesis for this article are available as an attached file in this published article.

Supplemental Material

Supplemental material for this article is available online.

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