ผลของการอบรมการช่วยฟื้นคืนชีพขั้นสูงแบบห้องเรียนกลับทางร่วมกับสถานการณ์จำลองต่อการคงอยู่ของความรู้ ทักษะ และความมั่นใจของนักศึกษาแพทย์ชั้นปีที่ 6

พนิตนันท์ จินดามณี[1]*, พิริยา ตรีรัตนพันธุ์[1]
[1] *กลุ่มงานเวชศาสตร์ฉุกเฉิน โรงพยาบาลตรัง*

*ผู้ประพันธ์บรรณกิจ
พนิตนันท์ จินดามณี
กลุ่มงานเวชศาสตร์ฉุกเฉิน โรงพยาบาลตรัง
ที่อยู่ 69 ถนนโคกขัน ตำบลทับเที่ยง อำเภอเมืองตรัง จังหวัดตรัง 92000
อีเมล: nitnan.jindamanee@gmail.com, nam_naja@hotmail.com
โทรศัพท์ที่ทำงาน: 075-201500 ต่อ 7110
โทรศัพท์มือถือ: 089 4725077

DOI: xxxxxx

วันที่รับบทความ: 2026-03-21
วันที่แก้ไขบทความ: 2026-04-10
วันที่ตอบรับบทความ: 2026-04-14

บทคัดย่อ

บทนำ

หัวใจหยุดเต้นเป็นภาวะฉุกเฉินที่ต้องการการช่วยฟื้นคืนชีพขั้นสูง (advanced cardiac life support) อย่างเร่งด่วน นักศึกษาแพทย์ชั้นปีที่ 6 ซึ่งเป็นส่วนหนึ่งของทีม ในการดูแลผู้ป่วยกลุ่มนี้ควรได้รับการฝึกอบรมอย่างเหมาะสม อย่างไรก็ตามความรู้และทักษะที่ได้รับจากการอบรมมักลดลงเมื่อเวลาผ่านไป การศึกษานี้มีวัตถุประสงค์เพื่อประเมินประสิทธิภาพของการอบรมการช่วยฟื้นคืนชีพขั้นสูงแบบระยะสั้นซึ่งประกอบด้วยการเรียนแบบ ห้องเรียนกลับทาง (flipped classroom) ร่วมกับการฝึกในสถานการณ์จำลอง ต่อการคงอยู่ของความรู้ ทักษะ และความมั่นใจของนักศึกษาแพทย์ชั้นปีที่ 6 ในการช่วยฟื้นคืนชีพขั้นสูง

วัตถุประสงค์

เพื่อศึกษาผลของการอบรมการช่วยฟื้นคืนชีพขั้นสูงระยะสั้นที่ใช้รูปแบบห้องเรียนกลับทางร่วมกับการจำลองสถานการณ์ต่อระดับความรู้ ทักษะ และความมั่นใจของนักศึกษาแพทย์ชั้นปีที่ 6

วิธีการศึกษา

เป็นการศึกษาแบบภาคตัดขวาง ดำเนินการระหว่างเดือนกันยายนถึงธันวาคม พ.ศ. 2567 ในกลุ่มนักศึกษาแพทย์ชั้นปีที่ 6 จำนวน 24 คน โรงพยาบาลตรัง โดยให้นักศึกษาวัดความรู้ด้วยแบบทดสอบจำนวน 30 ข้อ และประเมินทักษะก่อนการอบรม จากนั้นเปรียบเทียบระดับความรู้และทักษะการช่วยฟื้นคืนชีพก่อนอบรม หลังอบรมทันที และสามเดือนหลังการอบรม รวมถึงประเมินความมั่นใจก่อนอบรมและที่ระยะเวลา 3 เดือน วิเคราะห์ข้อมูลด้วย repeated measures ANOVA และ paired t-test

ผลการศึกษา

หลังการฝึกอบรมพบว่าคะแนนความรู้เฉลี่ยเพิ่มขึ้นจาก 18.15 ± 5.19 เป็น 21.35 ± 4.52 และยังคงเพิ่มขึ้นหลัง 3 เดือนเป็น 21.75 ± 3.26 ($p < 0.001$) คะแนนทักษะเพิ่มจาก 7.95 ± 2.11 เป็น 12.48 ± 1.78 และยังคงเพิ่มขึ้นหลัง 3 เดือนเป็น 14.38 ± 1.21 ตามลำดับ ($p < 0.001$) ระดับความมั่นใจเพิ่มขึ้นอย่างมีนัยสำคัญจาก 2.05 เป็น 4.40 ($p < 0.001$)

สรุป

การอบรมการช่วยฟื้นคืนชีพขั้นสูงระยะสั้น โดยการใช้ห้องเรียนกลับทางร่วมกับสถานการณ์จำลองสามารถเพิ่มและคงไว้ซึ่งความรู้ ทักษะ และความมั่นใจของนักศึกษาแพทย์ชั้นปีที่ 6 ได้อย่างมีประสิทธิภาพ เหมาะสมสำหรับนำไปประยุกต์ใช้ในศูนย์แพทย์ขนาดเล็กที่มีข้อจำกัดด้านเวลาและทรัพยากร

คำสำคัญ

การช่วยฟื้นคืนชีพขั้นสูง, การเรียนแบบพลิกกลับ, การจำลองสถานการณ์, นักศึกษาแพทย์, เวชศาสตร์ฉุกเฉิน

Retention of Advanced Cardiac Life Support (ACLS) Skills Following Simulation-Integrated Flipped Learning in Final-Year Medical Students

Panitnan Jindamanee[1]*, Piriya Treerattanapan[1]
[1] *Emergency Department, Trang hospital*

*coresponding author
Panitnan Jindamanee, MD
Emergency Department, Trang hospital
Trang Hospital 69 Khok Khan Rd., Thap Thiang, Mueang Trang, Trang 92000
Email: nitnan.jindamanee@gmail.com, nam_naja@hotmail.com
Tel. 075 201500 ext. 7110
Mobile: 089 4725077

DOI: xxxx

Receive date: 2026-03-21
Revised date: 2026-05-06
Accepted date: 2026-04-14

Abstract

Introduction

Retention of Advanced Cardiac Life Support (ACLS) skills is a common challenge in undergraduate medical education. Although ACLS is a critical competency for final-year medical students, there is limited research on how flipped-classroom methods combined with simulation-based training influence knowledge and skill retention beyond immediate post-training. This study evaluates the effectiveness of a brief ACLS course integrating these strategies to enhance knowledge, skills, and self-reported confidence in advanced resuscitation.

Objectives

To assess changes in knowledge, skills, and confidence among final-year medical students following a brief ACLS training using a flipped-classroom model integrated with simulation.

Methods

This cross-sectional study was conducted at Trang Hospital from September to December 2024. Twenty-four sixth-year medical students completed a 30-question knowledge test and a skills assessment before training. After the brief ACLS course, students were re-assessed on both knowledge and skills immediately after the training and again at three months. Confidence in applying ACLS was assessed before the training and at the three-month follow-up. Data were analyzed using repeated measures ANOVA and paired t-tests.

Results

Mean knowledge scores increased from 18.15 ± 5.19 (pre-test) to 21.35 ± 4.52 (post-test), and slightly increased to 21.75 ± 3.26 at three months ($p < 0.001$). Skills scores rose from 7.95 ± 2.11 to 12.48 ± 1.78, and further improved 14.38 ± 1.21 at follow-up ($p < 0.001$). Confidence scores rose from 2.05 to 4.40 ($p < 0.001$).

Conclusion

A brief ACLS training program integrating flipped learning and simulation effectively enhanced and sustained knowledge, clinical skills, and learner confidence among final-year medical students. This model provides a practical and scalable solution for ACLS education in resource-limited settings.

Keywords

Flipped learning; Cardiopulmonary resuscitation; Simulation; Medical education; Thailand

Introduction

Cardiac arrest is one of the leading causes of in-hospital mortality and requires immediate intervention to improve survival outcomes[1]. Delays in performing cardiopulmonary resuscitation (CPR) and defibrillation are associated with worse survival outcomes[2]. Healthcare professionals must be proficient in Advanced Cardiac Life Support (ACLS). In Thailand, final-year medical students (sixth-year) are expected to participate in emergency care during clinical rotations and contribute to resuscitation teams under supervision. Therefore, adequate ACLS training during undergraduate years is essential.

The standard ACLS course developed by the Thai Resuscitation Council (TRC) is typically delivered over two days and includes lectures and simulation sessions. While this format is suitable for provider certification, its implementation in undergraduate education presents logistical challenges. It is often difficult to apply this model broadly due to resource limitations, including time, costs, and instructor availability. Moreover, ACLS knowledge and skills are often not well retained over time. Hammond et al.[4] noted skill deterioration 18 months post-course, while Braun et al.[5] reported a similar decline within 6 months among certified providers. Consistent evidence shows that BLS knowledge and skills also begin to deteriorate within 3 to 6 months post-training[6-9]. These challenges raise concerns about how best to ensure skill retention among students with limited clinical exposure to real cardiac arrest events.

To address limitations in traditional ACLS training—such as limited learner engagement, time constraints, and suboptimal retention of skills—various modified instructional strategies have been implemented, including shortened course formats and flipped classroom models. The flipped classroom, which delivers foundational content through pre-class materials and reserves class time for active learning, has gained popularity in medical education. However, studies examining its application in ACLS training have yielded mixed results. For example, Beom et al.[10] found no significant difference in exam performance between flipped and traditional lecture-based instruction among senior medical students, suggesting that changes in content delivery alone may not be sufficient to enhance learning outcomes.

In contrast, Boysen-Osborn et al.[11] reported improved written test scores

when flipped classroom strategies were integrated into ACLS education. These findings imply that the flipped model may require integration with other evidence-based methods—such as simulation—to optimize learner engagement and support skill retention. Supporting this, Hybrid Team-Based ACLS Simulation programs combining online learning with team-based simulation have improved ACLS performance among nurses[12]. However, some brief ACLS training formats, such as Boonmak et al.[13], demonstrated immediate knowledge gains but showed a decline in practical skills after three months, highlighting the need for longitudinal reinforcement strategies. Despite various modifications, few studies have specifically examined the effectiveness of brief ACLS courses that integrate flipped learning with simulation for medical students. Current evidence remains limited regarding whether such combined models can sustain both knowledge and practical skills within the time constraints of undergraduate curricula. Therefore, this study aims to evaluate a brief ACLS training model incorporating a modified flipped classroom and simulation, to determine its impact on immediate learning outcomes and skill retention among final-year medical students.

Objectives

1. To evaluate the improvement in final-year medical students' knowledge and clinical skills before and after participating in a brief ACLS training that integrates flipped learning and simulation.
2. To assess the retention of ACLS knowledge and skills three months after the training.
3. To measure students' confidence in performing ACLS before training and at three-month follow-up.

Materials and Methods

Ethical Approval

The study protocol was reviewed and approved by the Ethics Committee of Trang Hospital (Approval No. 044/08-2567). All procedures were conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Study Design

The study was conducted at Trang Medical Education Center, a small regional teaching hospital in southern Thailand that enrolls approximately 24 final-year medical students per academic cycle. The center provides clinical training

across multiple specialties. Data collection took place over a four-month period, from September to December 2024.

Participants

Eligible participants were sixth-year medical students actively enrolled in clinical training at Trang Medical Education Center during the study period. Participation was voluntary, and written informed consent was obtained from all students prior to enrollment. Students were excluded if they were unable to complete the study procedures or had pre-existing physical conditions that could interfere with participation, such as cardiovascular disease. No participants were excluded during the study.

Instructional Design and Intervention

This study applied a flipped classroom model, in which students engaged in self-directed learning approximately one week prior to the in-person training session. Specifically, structured study guides were distributed in advance to facilitate at-home learning. These study guides (see Supplementary Material) included:

- ACLS algorithms
- Common medications used in resuscitation scenarios
- Methods for medication preparation
- Tips and mnemonics for memorizing algorithms to enhance comprehension
- A self-assessment tool to identify individual knowledge gaps in ACLS concepts

On the training day, participants underwent a standardized educational program including:

- A 30-minute instructor-led summary of key ACLS concepts
- A 90-minute hands-on simulation session, including scenario-based exercises, team collaboration, structured debriefing, and instructor-guided feedback

Participants were randomly assigned to small groups of 5–6, with each group working under the supervision of a trained instructor to promote team-based learning and active engagement.

Conceptual Framework

The instructional design of this course was informed by Kolb's experiential learning theory[14] and the flipped classroom model. Kolb's cycle includes four stages—Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation—which were mapped to specific course activities , as shown in Table 1.

Table 1 Alignment of Course Structure with Kolb's Experiential Learning Cycle and Flipped Classroom Principles

Learning Phase (Kolb's Cycle)	Flipped Classroom Component	Course Activities
1. Concrete Experience	Pre-class (self-directed learning)	Students reviewed structured ACLS study guides
2. Reflective Observation	Pre-class	Self-assessment checklist to reflect on knowledge gaps
3. Abstract Conceptualization	In-class (brief lecture)	30-minute instructor-led summary to reinforce theoretical understanding
4. Active Experimentation	In-class (simulation)	90-minute team-based simulation and debriefing under supervision

Data Collection

Baseline data were collected prior to the intervention, including participant demographics (age, sex), prior CPR experience, and self-assessed exposure to ACLS. Academic assessments were conducted at three time points.

Pre-training (Baseline Assessment):

Before receiving the study guides, participants completed baseline assessments to minimize bias from preparatory exposure. These included:

1. Knowledge Assessment

All participants completed a 30-item multiple-choice questionnaire based on the 2020 American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (see Supplementary Material). The questionnaire assessed three core domains:

1. High-quality CPR
2. ACLS algorithms
3. Electrocardiogram (ECG) interpretation

2. Skills Assessment

Participants' clinical skills were assessed using two randomly assigned scenarios derived from four standardized checklists, which were adapted directly from the official ACLS Instructor Manual to ensure alignment with the 2020 AHA Guidelines. Each scenario was designed to evaluate critical decision-making, adherence to resuscitation algorithms, and team-based performance during high-acuity cardiac events. The four

scenarios included:

Scenario 1: Cardiac arrest with ROSC followed by unstable bradycardia

Scenario 2: Tachycardia progressing to cardiac arrest

Scenario 3: Cardiac arrest (refractory VF) with transition to post-resuscitation care

Scenario 4: Drowning with cardiac arrest (PEA→VF)

Two independent assessors observed and scored each participant. The first assessor was a certified ACLS Provider, while the second had completed the ACLS Instructor Course. Both assessors had prior experience in simulation-based assessment and were familiar with ACLS educational principles. Prior to the study, both assessors reviewed and agreed upon the criteria for performance scoring to promote consistency.

3. Confidence Assessment

Participants rated their confidence in performing CPR using a structured self-report questionnaire administered prior to the training session

Immediate Post-training:

After the course, participants repeated the same knowledge and skills assessments.

Three-month Follow-up:

Twelve weeks later, the same assessments were administered again to evaluate retention of knowledge and skills, and confidence in performing ACLS.

Statistical Analysis

We compared pre- and post-training knowledge test scores, skill assessment scores, and confidence scores using repeated measures ANOVA and paired t-tests. A p-value of <0.05 was considered statistically significant. All analyses were performed using IBM SPSS Statistics Version 23.

Results

A total of 24 final-year medical students participated in the study (mean age 24.9 ± 0.6 years; 75% female). All had prior exposure to basic CPR training, but reported limited practical experience in ACLS, with a mean self-assessed exposure score of 2 out of 6.

Knowledge Retention

The mean pre-training knowledge score was 18.15 ± 5.19 out of 30. Following the intervention, this significantly increased to 21.35 ± 4.52 ($p < 0.001$). This improvement was sustained at 21.75 ± 3.26 during the 3-month follow-up, with no significant difference observed compared to the immediate post-training score (see Table 2).

Table 2 Knowledge score before, after and 3 months after ACLS training.

Knowledge Training	Knowledge score (Max 30) (Mean ± SD)	p-value†
Pre-test ACLS training (K1)	18.15 ± 5.19[a]	< 0.001
Post-test ACLS training (K2)	21.35 ± 4.52[b]	
After ACLS training 3 months (K3)	21.75 ± 3.26[c]	

K1 = Pre-training, K2 = Post-training, K3 = 3-Month Follow-up; SD = standard deviation; † Overall p-value by Repeated measures Anova; a Difference K2 vs K1 was 3.20 (95% CI: 0.88 to 5.52); b No significant difference between K2 and K3 (Mean difference = 0.40; 95% CI: -1.43 to 2.23); c Difference between K3 and K1 was 3.60 (95%CI: 1.72, 5.48).

Skill Development

Participants demonstrated significant improvements in ACLS skills. The mean pre-training score was 7.95 ± 2.11 (out of 20), which increased to 12.48 ± 1.78 immediately after the training ($p < 0.001$), and further improved to 14.38 ± 1.21 at the 3-month follow-up ($p < 0.001$). These improvements were both statistically and clinically significant, as shown in Table 3.

Confidence in ACLS Application

Self-reported confidence in performing CPR was assessed before training and at the three-month follow-up using a structured questionnaire with scores ranging from 1 (not confident) to 5 (very confident). Confidence scores improved significantly from a mean ± standard deviation (SD) of 2.05 ± 1.05 at baseline to 4.40 ± 0.82 at the three-month follow-up ($p < 0.001$), indicating increased learner confidence after the training program, as shown in Table 4.

Discussion

This study demonstrates that a brief ACLS training program combining flipped-classroom strategies and simulation significantly improved final-year medical students' knowledge, skills, and confidence. These gains were sustained at the three-month follow-up, supporting the model's effectiveness in short- to medium-term learning outcomes.

Knowledge scores increased from 18.15 before training to 21.35 after training and remained at 21.75 at follow-up. Unlike previous studies reporting rapid cognitive decline following conventional ACLS training[4-5,13], this sustained retention may be attributed to structured study guides that supported self-directed review and repeated rehearsal. This strategy

Table 3 Skill score before, after and 3 months after ACLS training.

Skill Training	Skill score (Max 20) (Mean ± SD)	p-value†
Pre-test ACLS training (S1)	7.95 ± 2.11[a]	< 0.001
Post-test ACLS training (S2)	12.48 ± 1.78[b]	
After ACLS training 3 months (S3)	14.38 ± 1.21[c]	

S1 = Pre-training, S2 = Post-training, S3 = 3-Month Follow-up; SD = standard deviation; † p-value by Repeated measures ANOVA; a Difference S2 vs S1 was 4.53 (95% CI: 4.08 to 4.97); b Difference S3 vs S2 was 1.90 (95% CI: 0.61 to 3.19); c Difference S3 vs S1 was 6.43 (95% CI: 5.04 to 7.81).

Table 4 Changes in Self-Reported Confidence Before Training and at Three-Month Follow-up

Time Point	Confidence Score (Mean ± SD)	p-value†
Pre-training (C1)	2.05 ± 1.05	< 0.001
Post-training 3 months(C2)	4.40 ± 0.82[a]	

C1 = Pre-training, C2 = Post-training (3 months); SD = standard deviation; † p-value by Paired t-test. a Difference C2 vs C1 was 2.35 (95% CI: 1.86 to 2.84).

reflects key principles of flipped learning, particularly learner autonomy and spaced repetition.

Skill scores not only improved immediately after training but continued to increase at the three-month follow-up. This trend contrasts with previous studies reporting post-training skill decay[5,6,15,16]. Several factors may explain this sustained improvement.

First, students were provided with structured study guides and reviewed content independently before class. Although this was not a fully digital flipped-classroom model, it incorporated the core principles of the approach. Pre-class preparation reduced lecture time, allowing more classroom time for simulation and feedback-based activities. This instructional shift has been shown to enhance learner engagement and improve practical skill development in health education[17].

Second, simulation sessions offered hands-on experience with immediate feedback, which supports long-term retention. Although clinical rotations were not part of this course, students had

opportunities to apply ACLS skills during these rotations, which may have reinforced their learning. Together, these factors encouraged learners to apply knowledge in realistic scenarios and reflect on their performance, supporting deeper learning aligned with Kolb's experiential learning framework[14]. The integration of cognitive preparation, practical rehearsal, and clinical application likely contributed to the consistent skill improvement observed in this cohort.

Confidence levels also increased significantly (from 2.05 to 4.40), likely due to the low-risk, hands-on simulation environment that encouraged active participation and reduced learner anxiety. Similar effects have been observed in simulation-based education studies involving healthcare trainees [18,19].

These findings have important implications for medical education, especially in resource-limited or time-constrained settings where lengthy training programs are impractical. The successful integration of a brief, structured ACLS course combining flipped-classroom pedagogy and high-fidelity simulation demonstrates that effective educational outcomes can be achieved within a condensed timeframe. As final-year medical students approach independent clinical practice, ensuring they retain essential resuscitation competencies is vital for patient safety. This model may serve as a reproducible framework for institutions seeking to optimize ACLS training in undergraduate curricula.

Limitation

This single-center study with a small sample size limits the generalizability of the findings. Future research should include multi-center trials with larger and more diverse cohorts to enhance external validity. In addition, the application of this brief flipped-classroom and simulation-based model should be explored in earlier stages of medical education and among other healthcare professionals.

Conclusion

This study supports the implementation of a brief ACLS training model incorporating flipped-classroom strategies and simulation in undergraduate medical education. The approach is effective in enhancing and sustaining knowledge, clinical skills, and learner confidence. This model provides a feasible, low-cost alternative to conventional ACLS courses, especially in resource-limited settings.

Funding

This study was supported by personal research funding.

Conflict of interest

The authors declare that they have no competing interests

References

1. Sandroni C, Nolan J, Cavallaro F, Antonelli M. In-hospital cardiac arrest: incidence, prognosis, and possible measures to improve survival. Intensive Care Med 2007;33(2): 237–45. doi:10.1007/s00134-006-0326-z
2. Valenzuela TD, Roe DJ, Cretin S, Spaite DW, Larsen MP. Estimating effectiveness of cardiac arrest interventions: a logistic regression survival model. Circulation 1997;96(10):3308–13. doi:10.1161/01.CIR.96.10.3308
3. Thai Resuscitation Council. 2020 ACLS Provider Course (Instructor-Led Training) FAQ [Internet]. Bangkok: Thai Resuscitation Council; 2020 [cited 2024 Aug 1]. Available from: https://www.thaicpr.org/get_attachment.php?attachment_id=46129&passcode=e0e840797e83d7cf537d4a0efd4b7724.
4. Hammond F, Saba M, Simes T, Cross R. Advanced life support: retention of registered nurses' knowledge 18 months after initial training. Aust Crit Care 2000;13(3):99–104. doi:10.1016/S1036-7314(00)70632-1
5. Braun TA, Bunting PC, Sikkink CJ, Tarby CM. Skill decay in advanced life support: a prospective observational study. Emerg Med J 2006;23(10):747–9.
6. Sripara P.Effects ofACLS simulation-based learning program to knowledge and skill for nurses in KosumphisaiHospital, Mahasarakhamprovince UBRU Journal for Public Health Researchวารสาร 2021;10(1): 26–35.
7. Srivilaithon W, Amnuaypattanapon K, Limjindaporn C, Diskumpon N, Dasanadeba I, Daorattanachai K. Retention of basic-life-support knowledge and skills in second-year medical students. Open Access Emerg Med 2020;12:211–7. doi:10.2147/OAEM.S241598
8. Smith KK, Gilcreast D, Pierce K. Evaluation of skill performance and retention in BLS and ACLS training. Resuscitation 2008;78(3):326-31. doi:10.1016/j.resuscitation.2008.02.007
9. Sivrikaya U, Kizilkar S, Oner C, Saribek F, Gulsen MF, Sukayar E. Emergency Medical Technicians' LongTerm Retention Following Cardiopulmonary Resuscitation Training: A Follow Up Study. Emergency Medicine Investigations 2020;5(45):1–7.
10. Beom J, Kim JH, Chung H, Kim S, Ko D, Cho J. Flipped-classroom training in advanced cardiopulmonary life support. PLoS One 2018;13(8):e0203114. doi:10.1371/journal.pone.0203114
11. Boysen-Osborn M, Anderson CL, Navarro R, Yanuck J, Strom S, McCoy CE, et al. Flipping the Advanced Cardiac Life Support Classroom with Team-based Learning: Comparison of Cognitive Testing Performance for Medical Students. J Educ Eval Health Prof 2016;13:11. doi:10.3352/jeehp.2016.13.11
12. Jeong HW, Ju D, Lee AK, Lee JA, Kang NR, Choi EJ, Ahn SH, Moon SH. Effect of a hybrid team-based advanced cardiopulmonary life support simulation program for clinical nurses. PLoS One 2022;17(12):e0278512. doi:10.1371/journal.pone.0278512
13. Boonmak P, Boonmak S, Srichaipanha S, Poomsawat S. Knowledge and skill after brief ACLS training. J Med Assoc

Thai 2004;87(11):1311–4.

14. Kolb DA. Experiential learning: Experience as the source of learning and development. Englewood Cliffs, NJ: Prentice Hall; 1984.
15. Reihani H, Jafari N, Ebrahimi M, Pishbin E, Bolvardi E, Vakili V. Improving advanced cardiovascular life support skills in medical students: simulation-based education approach. Journal of Emergency Practice and Trauma 2015;1(1):7–11.
16. Lo BM. Comparison of traditional versus high-fidelity simulation in the retention of ACLS knowledge. Resuscitation 2011; 82(11):1440-3. doi:10.1016/j.resuscitation.2011.06.017
17. Al-Samarraie H, Saeed N, Saqr M, Shukor NA, Shubashini R, Abdul Kareem A, et al. Flipped learning in health professions education: a scoping review on pedagogical models, technological tools, and educational outcomes. Int J Educ Technol High Educ. 2023;20(1):36. doi:10.1186/s41239-023-00430-5.
18. Ogilvie S, Cragg B, Foulds B. Perceptions of nursing students on the process and outcomes of a simulation experience. Nurse Educ 2011;36(2):56–8. doi:10.1097/NNE.0b013e31820b4fd5
19. Ander DS, Heilpern K, Goertz F, Click L, Kahn S. Effectiveness of a simulation-based medical student course on managing life-threatening medical conditions. Simul Healthc 2009;4(4):207–11. doi:10.1097/SIH.0b013e3181a9dd84