

Implementation of a microlearning-based educational program for continuous renal replacement therapy in a Magnet-recognized intensive care unit: effects on nursing competence and patient safety

Danilo Batista de Almeida

danilo.enf@hotmail.com

Hospital Israelita Albert Einstein

Elaine Monico Raimundo

Hospital Israelita Albert Einstein

Marcele Liliane Pesavento

Hospital Israelita Albert Einstein

Research Article

Keywords: microlearning, continuous renal replacement therapy, critical care nursing, nursing education, patient safety, intensive care unit

Posted Date: August 13th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10354820/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background: Continuous renal replacement therapy (CRRT) is a complex, high-risk intervention for critically ill patients with acute kidney injury and hemodynamic instability. Safe delivery requires nursing competence, rapid troubleshooting, and adherence to protocols. However, conventional education is difficult to sustain in intensive care units because of workload, rotating shifts, and competing clinical priorities. This study evaluated whether a structured microlearning program was associated with changes in CRRT knowledge, self-confidence, and satisfaction among intensive care nursing professionals.

Methods: A retrospective observational pre-post study was conducted in the adult intensive care unit of a Magnet-recognized hospital in São Paulo, Brazil. Nurses and nursing technicians validated to manage CRRT completed 16 microlearning modules lasting 3–5 minutes. Knowledge was assessed using an 18-item theoretical-practical questionnaire, self-confidence using a Likert scale, and satisfaction using the Net Promoter Score (NPS). Pre-post comparisons used the Wilcoxon signed-rank test, with rank-biserial correlation as the effect-size measure. Pearson and Spearman coefficients examined associations between knowledge and self-confidence gains.

Results: Of 143 professionals, 126 completed the program, yielding an 88.1% retention rate; 63 were nurses and 63 nursing technicians. Mean knowledge scores increased from 14.39 ± 1.46 to 16.73 ± 1.45 , an average gain of 2.34 points ($p < 0.001$; effect size = 0.92). Self-confidence increased from 9.47 ± 0.87 to 9.70 ± 0.90 ($p = 0.003$; effect size = 0.57). Knowledge gain was not correlated with self-confidence gain. Satisfaction was high: 119 participants were promoters, five were passives, and two were detractors, resulting in an NPS of 92.9%.

Conclusion: The structured microlearning program was associated with improved CRRT knowledge, greater self-confidence, and high acceptability among intensive care nursing professionals. Its sequential format was feasible across shifts and may offer a scalable approach to continuing education for high-risk extracorporeal therapies. Further multicenter studies should evaluate long-term knowledge retention, behavioral change, and patient-level safety outcomes.

Implications for Practice: Microlearning can complement competency validation, simulation, bedside coaching, and audit-feedback strategies. Embedding concise modules within routine work may reinforce CRRT protocols, standardize troubleshooting and monitoring practices, support multidisciplinary escalation pathways, and reduce barriers to continuing education for shift-based teams in high-acuity environments.

Background

Acute kidney injury is a frequent and serious complication among critically ill patients. When kidney dysfunction is severe or accompanied by fluid overload, metabolic derangements or uremic complications, kidney replacement therapy may be required. In hemodynamically unstable patients,

continuous renal replacement therapy (CRRT) is commonly selected because it enables slower and more continuous removal of fluid and solutes.^(1–3, 11, 12) The clinical benefit of CRRT, however, depends not only on the prescription but also on safe delivery at the bedside.^(1, 2, 11)

Nursing professionals have a central role in CRRT delivery. Their responsibilities include preparing and priming the extracorporeal circuit, assessing vascular access, monitoring prescribed and delivered therapy, interpreting machine alarms, documenting fluid balance, observing anticoagulation-related complications, preventing circuit clotting, maintaining infection prevention practices and recognizing early clinical deterioration.^(4–7) These activities occur within a dynamic intensive care unit (ICU) environment characterized by high acuity, frequent interruptions and competing priorities. Errors or delays during CRRT may lead to therapy interruption, blood loss, inadequate dose delivery, hemodynamic instability and avoidable patient harm.^(6, 7, 13)

Consequently, CRRT education must move beyond introductory training and support continuous competence development. Conventional models commonly include lectures, supervised practice and competency validation.^(4–7) These strategies remain essential for initial skills acquisition, but they may be difficult to repeat frequently in busy units with rotating shifts and a heterogeneous workforce. Long educational sessions can also increase cognitive burden and may not align well with the way clinicians acquire and retrieve information during clinical practice.^(15, 25, 26)

Microlearning has emerged as an educational strategy that delivers concise content in small, focused units.^(15, 21) Its theoretical foundation is compatible with cognitive load theory, which recognizes that working memory has limited capacity when learners process complex information.⁽²⁶⁾ By reducing each learning unit to a specific theme or task, microlearning may make complex content more manageable. It is also consistent with adult learning principles, as it can be delivered close to practice, revisited when needed and integrated into routine work without requiring prolonged absence from clinical duties.^(25, 26)

Health professions education literature suggests that microlearning may improve engagement, knowledge acquisition, self-efficacy and satisfaction.^(15–24) Recent nursing education studies and reviews have expanded interest in mobile microlearning, small-dose learning and technology-enhanced professional development.^(16–24) However, evidence remains limited for high-risk extracorporeal therapies, particularly CRRT in adult ICUs.^(8, 13, 14) This gap is important because CRRT is both technically complex and highly dependent on bedside nursing surveillance.^(8, 13) A scalable educational intervention that reinforces essential concepts over time could help standardize practice and strengthen patient safety.^(9, 10, 13)

The present study evaluated an institutional microlearning program implemented for nursing professionals validated to manage CRRT in an adult ICU. The aim was to assess whether the intervention was associated with changes in CRRT knowledge, self-confidence and satisfaction among intensive care nursing professionals.

Methods

This was a retrospective observational pre-post study based on data collected during an institutional continuing education program for CRRT. The intervention had already been implemented as part of routine professional development before the retrospective research analysis was conducted. The study was performed in the adult intensive care unit of Hospital Israelita Albert Einstein, a tertiary referral hospital in São Paulo, Brazil, which holds Magnet® designation from the American Nurses Credentialing Center (ANCC). The institution maintains a structured nephrology support program and a formal competency-validation process for CRRT management.

The target population comprised nurses and nursing technicians formally validated by the institutional dialysis center to manage CRRT. The eligibility criteria included: currently working in the adult ICU; having institutional approval to manage CRRT; being directly involved in CRRT care, such as setting up circuits, monitoring parameters, and managing procedures; participating in the microlearning program; and having both pre- and post-intervention educational assessments available. Professionals on medical leave, no longer working in the institution, transferred out of direct care or without complete training exposure were excluded from the analytic sample.

The educational intervention consisted of 16 sequential microlearning modules delivered weekly (Table 1). Each module lasted approximately 3–5 minutes and focused on a specific component of CRRT practice. The curriculum covered the complete nursing workflow, including principles of CRRT, indications, circuit preparation, vascular access, anticoagulation, filter clotting prevention, alarm management, fluid balance, dose delivery, laboratory monitoring, mobilizations, infection prevention, dressing care, institutional flows, patient safety and prevention of adverse events. The short format was designed to reduce cognitive overload, facilitate repetition and allow learning to occur alongside routine ICU practice.

Table 1
Microlearning curriculum

Module	Topic	Educational focus
1	Principles of CRRT	Core concepts, terminology and therapy rationale
2	Indications and contraindications	Clinical scenarios and institutional activation criteria
3	Circuit preparation	Preparation, priming and readiness checks
4	Vascular access	Assessment, positioning and access-related complications
5	Anticoagulation	Regional anticoagulation concepts and monitoring
6	Filter clotting prevention	Risk factors, early recognition and preventive actions
7	Alarm management	Prioritization and troubleshooting of machine alarms
8	Fluid balance	Prescription, documentation and cumulative balance control
9	Dose delivery	Prescribed versus delivered therapy and interruptions
10	Laboratory monitoring	Key laboratory tests and timing of collection
11	Patient mobilization	Safe movement of patients undergoing CRRT
12	Infection prevention	Aseptic practices and circuit-related precautions
13	Dressing management	Catheter dressing surveillance and care
14	Institutional flows	Local protocols and escalation pathways
15	Patient safety	Checklist use and prevention of operational errors
16	Adverse event prevention	Recognition, response and reporting of complications
Note. CRRT = continuous renal replacement therapy.		

The primary outcome was the change in continuous renal replacement therapy (CRRT) knowledge, assessed using an 18-item theoretical-practical questionnaire developed by the author and administered before and after the program. The secondary outcomes were self-confidence in CRRT management, assessed using a Likert scale at the same time points, and satisfaction with the educational program, measured at the end of the intervention using the Net Promoter Score (NPS). NPS responses were classified as promoters for scores of 9–10, passives for scores of 7–8 and detractors for scores of 0–6. The final NPS was calculated by subtracting the percentage of detractors from the percentage of promoters.

Data were analyzed using descriptive and inferential statistics. Continuous variables were summarized as mean and standard deviation, and categorical variables as absolute and relative frequencies.

Normality was assessed with the Shapiro-Wilk test. Because knowledge and self-confidence distributions were non-normal, pre-post comparisons were performed using the Wilcoxon signed-rank test. Effect size for paired non-parametric comparisons was calculated using the rank-biserial correlation coefficient. Correlation between knowledge gain and self-confidence gain was assessed using Pearson and Spearman coefficients. Statistical significance was defined as $p < 0.05$.

To reduce potential bias, only participants with complete pre- and post-intervention assessments were included in the final analysis. The educational intervention was delivered uniformly across all shifts using standardized content.

The sample size was determined by the number of nursing professionals eligible for the institutional CRRT educational program during the study period.

This study was approved by the Research Ethics Committee of Hospital Israelita Albert Einstein (CAAE No. 91130625.1.0000.0071; Ethics Committee Approval No. 8.296.998) and was conducted in accordance with the ethical principles of the Declaration of Helsinki, the Brazilian National Health Council Resolution No. 466/2012, and all applicable national regulations. The requirement for informed consent was waived by the Research Ethics Committee because this retrospective observational study used anonymized data collected during routine clinical practice, with no direct participant involvement.

Results

A total of 143 nursing professionals were eligible for the institutional program. Seventeen were lost to follow-up, mainly because they were no longer providing direct care, were on medical leave, had left the institution, had left the ICU or had not completed CRRT training. Thus, 126 participants completed the intervention, corresponding to a retention rate of 88.1% (Table 2). The analysis included 126 professionals with matched pre- and post-intervention data.

Table 2
Participant flow

Stage	n	%
Eligible professionals	143	100.0
Completed the microlearning program	126	88.1
Lost to follow-up	17	11.9

Among the 126 completers, 63 were nurses and 63 were nursing technicians. Most participants were female ($n = 82$; 65.1%). Mean age was 36.1 ± 7.8 years. Mean time since professional training was 11.4 ± 6.4 years, and mean time in the nephrology support team or CRRT-related role was 5.5 ± 4.0 years. Participants were distributed across day and night shifts, supporting the feasibility of the program across different staffing patterns (Table 3).

Table 3
Baseline characteristics of completers (n = 126)

Characteristic	Value
Age, years, mean +/- SD	36.1 +/- 7.8
Female, n (%)	82 (65.1)
Male, n (%)	44 (34.9)
Nurses, n (%)	63 (50.0)
Nursing technicians, n (%)	63 (50.0)
Time since professional training, years, mean +/- SD	11.4 +/- 6.4
Time in nephrology/CRRT role, years, mean +/- SD	5.5 +/- 4.0
Day shift A, n (%)	32 (25.4)
Day shift B, n (%)	31 (24.6)
Night shift A, n (%)	34 (27.0)
Night shift B, n (%)	29 (23.0)
Note. CRRT = continuous renal replacement therapy; SD = standard deviation.	

Knowledge improved after the microlearning program. Mean scores increased from 14.39 +/- 1.46 to 16.73 +/- 1.45, representing an average gain of 2.34 points on an 18-item instrument. The Wilcoxon signed-rank test showed a statistically significant difference between pre- and post-intervention scores ($p < 0.001$). The paired rank-biserial effect size was 0.92, indicating a large educational effect (Table 4).

Table 4
Educational outcomes before and after microlearning

Outcome	Pre-intervention	Post-intervention	Mean change	p-value	Effect size
Knowledge score (18 items)	14.39 +/- 1.46	16.73 +/- 1.45	+ 2.34	< 0.001	0.92
Self-confidence Likert score	9.47 +/- 0.87	9.70 +/- 0.90	+ 0.23	0.003	0.57
Note. Values are mean +/- SD. Comparisons used the Wilcoxon signed-rank test. Effect size is rank-biserial correlation.					

Self-confidence also improved. Mean Likert scores increased from 9.47 +/- 0.87 before the intervention to 9.70 +/- 0.90 after the intervention. Although baseline confidence was already high, the Wilcoxon signed-rank test showed a statistically significant improvement ($p = 0.003$), with a moderate-to-large rank-biserial effect size of 0.57.

Knowledge gain was not correlated with self-confidence gain. Pearson correlation was -0.011 ($p = 0.899$), and Spearman correlation was 0.004 ($p = 0.966$). This suggests that participants with larger knowledge gains were not necessarily those with larger changes in self-confidence, possibly because confidence scores were high at baseline and showed a ceiling effect.

Satisfaction with the program was high. The mean NPS score was 9.70 ± 0.80 . Of 126 completers, 119 were classified as promoters, five as passives and two as detractors, resulting in an NPS of 92.9% (Table 5). These findings indicate high acceptance of the microlearning strategy among ICU nursing professionals.

Table 5
Satisfaction with the microlearning program (n = 126)

NPS category	Definition	n (%)
Promoters	Scores 9–10	119 (94.4)
Passives	Scores 7–8	5 (4.0)
Detractors	Scores 0–6	2 (1.6)
Final NPS	% promoters - % detractors	92.9%
Note. NPS = Net Promoter Score.		

Discussion

This study found that a structured microlearning program was associated with significant improvements in CRRT knowledge and self-confidence among nursing professionals working in an adult ICU. The intervention also achieved high participant satisfaction, with more than 90% of respondents classified as promoters. These findings suggest that microlearning can be integrated into critical care nursing education for complex therapies without requiring prolonged classroom-based training.^(15–24)

The increase in knowledge was clinically and educationally relevant. Participants improved by more than two points on an 18-item questionnaire, and the effect size was large. This is important because CRRT management depends on accurate recall and application of multiple technical and safety-related concepts. Nurses and nursing technicians must recognize alarm priorities, protect vascular access, prevent filter clotting, monitor fluid balance and respond rapidly to therapy interruptions.^(4–7, 13) Knowledge gaps in these areas may result in delayed troubleshooting or inconsistent application of protocols.

The findings are consistent with the broader CRRT literature emphasizing structured training, specialist teams and process standardization.^(4–10) Recent multicenter survey evidence has shown that CRRT knowledge, attitudes and practice are influenced by years of CRRT experience, education level, teaching-hospital context and membership in specialist panels.⁸ These findings support the premise that CRRT

competence is not a static attribute acquired once, but a professional capability shaped by repeated exposure, local systems and continuing education.

Quality improvement studies in CRRT further reinforce the relevance of bedside nursing competence. Initiatives that allow trained unit-based nurses to initiate or restart CRRT have been associated with marked reductions in delays and improved treatment continuity.⁽¹⁰⁾ Specialist quality-control programs have reported improvements in circuit life, unplanned interruption rates, catheter-related infection rates, treatment costs and nursing satisfaction.⁽⁹⁾ Collectively, these studies suggest that educational and organizational interventions may contribute to safer and more efficient CRRT delivery.

Patient safety literature also highlights the complexity of CRRT as a sociotechnical process. Risk assessments of CRRT identify clotted filters, anticoagulation-related bleeding, catheter-related bloodstream infection, variability in machine-related proficiency, high nursing workload, staff turnover, electrolyte disturbances, prescribing variability and communication failures as recurrent risk domains.⁽¹³⁾ The curriculum used in this study addressed many of these domains through focused modules on alarms, anticoagulation, fluid balance, dose delivery, infection prevention, institutional flows and adverse event prevention.

The improvement in self-confidence deserves careful interpretation. Baseline confidence was already high, which may reflect the fact that all participants were previously validated for CRRT management. Even so, confidence increased significantly after the intervention. This suggests that the program may have reinforced prior knowledge, clarified institutional expectations and provided professionals with a greater sense of preparedness. In high-risk therapies, confidence should not be understood as a substitute for competence, but appropriate self-confidence may support timely decision-making and reduce hesitation during troubleshooting.^(7, 8)

The lack of correlation between knowledge gain and self-confidence gain is also informative. Participants who improved most in knowledge were not necessarily those who reported the greatest increase in confidence. Several explanations are possible. First, self-confidence scores were high at baseline, creating a ceiling effect. Second, knowledge and confidence may represent related but distinct educational outcomes. Third, some participants may have become more aware of the complexity of CRRT after the program, which could temper confidence despite improved knowledge. Future studies should include objective performance assessment, simulation-based evaluation or direct observation to explore how knowledge, confidence and behavior interact.⁽¹⁴⁾

High satisfaction is another relevant finding. The NPS of 92.9% indicates strong acceptance of the program. In ICU education, acceptability is not a secondary concern; even well-designed educational strategies may fail if they are impractical for shift-based clinical teams. The short duration of each module, weekly delivery and direct alignment with bedside tasks likely contributed to engagement. This is particularly relevant for critical care settings, where staffing pressures and patient acuity often limit participation in traditional education.

Microlearning findings from nursing education are consistent with this interpretation. Studies involving nursing students and ICU nurses have reported positive effects of microlearning or mHealth-based microlearning on knowledge, self-efficacy, satisfaction, stress and anxiety.^(16–24) Recent reviews have also highlighted the value of mobile microlearning and technology-enhanced learning for continuing professional development in nursing, particularly when educational content is distributed over time and aligned with clinical practice.^(15, 19, 21, 24) The present study extends this literature by applying microlearning to CRRT, a high-risk extracorporeal therapy with direct implications for patient safety.

From a patient safety perspective, microlearning may provide a mechanism for reinforcing standardized practices. CRRT involves many steps vulnerable to variation, including circuit setup, alarm response, anticoagulation monitoring, fluid balance documentation and escalation of complications.^(1, 6, 11, 13) Short modules can be aligned with institutional protocols and repeatedly updated as practice evolves. This format may help translate policy into bedside behavior, especially when paired with checklists, competency validation and clinical leadership support.^(9, 13)

The study also has implications for nursing leadership. Educational interventions in critical care should be feasible, measurable and scalable. The program described here used existing institutional data, achieved high retention and generated measurable outcomes. Such an approach can support continuous professional development while producing evidence for quality improvement. Nurse leaders may consider microlearning as part of a broader education strategy that includes simulation, bedside coaching, audit and feedback, and periodic competency review.^(10, 14) The program was implemented in a Magnet®-designated institution, where organizational support for professional development, evidence-based practice and continuous quality improvement may have facilitated staff engagement and program adoption. However, the observed educational outcomes cannot be attributed solely to the Magnet® environment and should be interpreted within the broader context of the intervention.

Several strengths should be noted. The intervention was implemented in a real adult ICU, involved both nurses and nursing technicians, and included professionals across shifts. The sample was relatively large for a single-center educational study, and the retention rate was high. The study also examined multiple outcomes, including knowledge, self-confidence, satisfaction and correlation between educational gains.

Future research should evaluate microlearning in multicenter designs and include longer follow-up periods. Studies should assess whether gains in knowledge and confidence translate into behavioral changes and improved CRRT quality indicators. Combining microlearning with simulation and bedside competency assessment may provide a more complete educational model for high-risk extracorporeal therapies.^(14, 15, 21)

Limitations

Limitations must also be acknowledged. The retrospective pre-post design does not allow causal inference with the same strength as a randomized controlled trial. There was no control group, and improvements may have been influenced by concurrent clinical exposure or other educational activities. The study was conducted in a single tertiary hospital with an established CRRT validation process, which may limit generalizability to institutions with different staffing models or educational infrastructure. Knowledge retention was measured immediately after the intervention, and long-term retention was not evaluated. Finally, the study did not assess patient-level outcomes, such as circuit life, treatment interruptions, delivered dose, adverse events or documentation quality.^(9–13)

Conclusion

A structured microlearning program was associated with improved CRRT knowledge, increased self-confidence and high satisfaction among intensive care nursing professionals. The intervention was feasible in a real ICU environment and may represent a scalable strategy for continuing professional development in high-risk critical care therapies. Further studies should evaluate long-term retention, behavioral outcomes and patient safety indicators.

Abbreviations

- ANCC
American Nurses Credentialing Center
- CAAE
Certificate of Presentation for Ethical Consideration
- CRRT
continuous renal replacement therapy
- NPS
Net Promoter Score
- ICU
intensive care unit

Declarations

Ethics approval and consent to participate

Ethics statement

Research Ethics Committee of Hospital Israelita Albert Einstein; CAAE 91130625.1.0000.0071; approval number 8,296,998; approved 20 March 2026. CONEP review was not required.

Consent for publication

“Not applicable”

Availability of data and materials

The datasets generated and/or analysed during the current study are available in the Zenodo repository, DOI 10.5281/zenodo.21510440.

Competing interest

The authors declare no competing interests. This statement should be confirmed by all authors before submission.

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with scientific translation, grammatical revision, and refinement of academic writing. All generated content was carefully reviewed, validated, and edited by the authors, who assume full responsibility for the final content submitted for publication.

All authors read and approved the final version of the manuscript.

Funding source information

This study received no external funding. The project was supported by institutional resources.

Author Contributions

Danilo Batista de Almeida: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Visualization.

Marcele Liliane Pesavento: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

Elaine Monico Raimundo: Supervision, Validation, Writing – review & editing.

References

1. Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group. KDIGO Clinical Practice Guideline for Acute Kidney Injury. *Kidney Int Suppl.* 2012;2(1):1-138.
2. Ostermann M, Joannidis M, Pani A, et al. Patient selection and timing of continuous renal replacement therapy. *Blood Purif.* 2016;42(3):224-237.
3. Hoste EAJ, Bagshaw SM, Bellomo R, et al. Epidemiology of acute kidney injury in critically ill patients: the multinational AKI-EPI study. *Intensive Care Med.* 2015;41(8):1411-1423.
4. Baldwin I. Training, management, and credentialing for continuous renal replacement therapy in the intensive care unit. *Am J Crit Care.* 1997;6(5):356-361.
5. Przybyl H, Evans J. Training and maintaining: developing a successful and dynamic continuous renal replacement therapy program. *AACN Adv Crit Care.* 2017;28(1):41-50.

6. Richardson A, Whatmore J. Nursing essential principles: continuous renal replacement therapy. *Nurs Crit Care*. 2015;20(1):8-15.
7. Calabrese E, et al. Nursing competence in continuous renal replacement therapy: development and validation of a measurement tool. *J Ren Care*. 2022;48(1):31-40. doi:10.7429/pi.2022.754218.
8. Yu X, Ouyang L, Li J, et al. Knowledge, attitude, practice, needs, and implementation status of intensive care unit staff toward continuous renal replacement therapy: a survey of 66 hospitals in central and South China. *BMC Nurs*. 2024;23:281. doi:10.1186/s12912-024-01953-6.
9. Xu X, Wang M, Wang Y, et al. Effect of ICU specialist care quality control team management program in continuous renal replacement therapy: A retrospective comparative study. *Medicine*. 2026;104:e42710. doi:10.1097/MD.00000000000042710.
10. Cordoza M, Rachinski K, Nathan K, et al. A Quality Improvement Initiative to Reduce the Frequency of Delays in Initiation and Restarts of Continuous Renal Replacement Therapy. *J Nurs Care Qual*. 2021;36(4):308-314. doi:10.1097/NCQ.0000000000000557.
11. Galindo P, Neyra JA. Continuous Renal Replacement Therapy: What Have We Learned And What Are Key Milestones For The Years To Come? *Rev Invest Clin*. 2023;75(6):348-358. doi:10.24875/RIC.23000221.
12. Saunders H, Rehan A, Hashmi MF, Sanghavi DK. Continuous Renal Replacement Therapy [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 [cited 2026 Jun 19]. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK556028/>
13. Saad A, Alsadi J, Al-Absi DT, et al. An integrative risk assessment approach to enhancing patient safety in Continuous Renal Replacement Therapy (CRRT). *Journal of Safety Science and Resilience*. 2024;5:344-354. doi:10.1016/j.jnlssr.2024.04.003.
14. Raina R, Kirpalani A, Sivaram P, Pantelakis N, Rajasegaran P, Sethi SK, et al. Advancing Continuous KRT Education: Simulation and Technology-Enhanced Learning in Contemporary Practice. *Kidney360*. Year;Volume(Issue):pages. doi:10.34067/KID.0000001288.
15. De Gagne JC, Park HK, Hall K, Woodward A, Yamane S, Kim SS. Microlearning in health professions education: scoping review. *JMIR Med Educ*. 2019;5(2):e13997.
16. Haghighat H, Shiri M, Esmaili Abdar M, et al. The effect of micro-learning on trauma care knowledge and learning satisfaction in nursing students. *BMC Med Educ*. 2023;23:622. doi:10.1186/s12909-023-04609-2.
17. Zarshenas L, Mehrabi M, Karamdar L, Keshavarzi MH, Keshtkaran Z. The effect of micro-learning on learning and self-efficacy of nursing students: an interventional study. *BMC Med Educ*. 2022;22:664. doi:10.1186/s12909-022-03726-8.
18. Abbasalizadeh M, Farsi Z, Sajadi SA, Atashi A, Fournier A. The effect of resilience training with mHealth application based on micro-learning method on the stress and anxiety of nurses working in intensive care units: a randomized controlled trial. *BMC Med Educ*. 2024;24:442. doi:10.1186/s12909-024-05427-w.

19. McCarthy AK, Agnew JD, Price J, Strang K, McLaughlin A. Transforming Health Care AI Education Through Micro-learning: A Novel Partnership Model for Nursing Workforce Development. CIN: Computers, Informatics, Nursing. doi:10.1097/CIN.0000000000001535.
20. Boyd E, Lynch M, Coates V, Vanharen Y, Chamos AJ. Educational interventions to improve electrocardiogram interpretation competence among nurses: A systematic review. Nurse Educ Pract. 2026;94:104856. doi:10.1016/j.nepr.2026.104856.
21. Mobile Microlearning in Continuing Professional Development for Nursing: A Scoping Review. J Contin Educ Nurs. 2025;volume(issue):pages. doi:10.3928/00220124-20250121-05.
22. Learning in small doses, impact in big ways: Effects of mobile microlearning on patient safety competency in nursing students. Nurse Educ Pract. 2026;volume:104880. doi:10.1016/j.nepr.2026.104880.
23. Tuma F, Nassar AK. Applying Bloom's taxonomy in clinical surgery: Practical examples. Ann Med Surg. 2021;69:102656. doi:10.1016/j.amsu.2021.102656.
24. Budi SC, Putri DGP, Puspitasari K, Sena AR. Implementation of the Digital Health Approach to Support Learning for Health Students Based on Bloom's Taxonomy: A Systematic Review. Healthc Inform Res. 2024;30(4):387-397. doi:10.4258/hir.2024.30.4.387.
25. Knowles MS, Holton EF, Swanson RA. The Adult Learner: The Definitive Classic in Adult Education and Human Resource Development. 8th ed. New York: Routledge; 2015.
26. Van Merriënboer JJG, Sweller J. Cognitive load theory in health professional education: design principles and strategies. Med Educ. 2010;44(1):85-93.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [ContinuousRenalReplacementTherapyTrainingQuestionnaireEN.docx](#)