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# DIGITAL LEARNING METHODS TO IMPROVE PEDIATRIC DRUG DOSAGE CALCULATION SKILLS IN NURSING STUDENTS: A SYSTEMATIC LITERATURE REVIEW

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## ABSTRACT

Pediatric medication dosage calculation errors remain a major contributor to medication errors and can adversely affect pediatric patient safety. Nursing students often experience difficulties with weight-based dosage calculations and unit conversions, highlighting the need for innovative digital-based learning approaches. Aim To analyze the effectiveness of digital-based learning methods in improving pediatric medication dosage calculation skills among nursing students. A systematic literature review was conducted in accordance with the PRISMA 2020 guidelines, with searches performed across eight international databases for studies published between 2015 and 2025. The inclusion criteria comprised quasi-experimental studies and randomized controlled trials. Study quality was assessed using the Joanna Briggs Institute (JBI) checklists, and the findings were synthesized narratively. Nine studies met the inclusion criteria. The interventions included mobile learning, e-learning, video-based learning, blended learning, instant messaging applications, interactive multimedia, and digital collaborative platforms. Most studies reported significant improvements in dosage calculation accuracy and student self-efficacy, particularly with blended learning and mobile learning approaches. Digital-based learning may improve pediatric medication dosage calculation skills and has the potential to support patient safety. Integrating digital learning methods into nursing curricula and conducting long-term, multicenter randomized controlled trials are recommended.

Keywords: digital learning, pediatric dosage calculation, nursing students, systematic literature review

## INTRODUCTION

Medication dosing errors in children are a serious public health issue, as nearly all pediatric therapies require dose adjustments based on body weight, age, or body surface area. This process involves several mathematical steps, such as unit conversion and drug concentration adjustment, thereby increasing the potential for errors. The WHO emphasizes that children are at higher risk of medication errors because their therapeutic range is narrower and many medications lack formulations specifically designed for children (WHO, Technical Report on Medication Safety, 2021). Inaccurate calculations can result in underdosing, rendering therapy ineffective, or overdosing, which can lead to serious side effects. Furthermore, physiological differences between children and adults further complicate dose calculations, which can lead to serious complications, even life-threatening ones (Puangsuwan et al., 2025; Norouzi et al.,

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2025). This situation highlights that calculating pediatric medication doses is a complex and high-risk process, making it a primary focus in pediatric patient safety as well as a priority issue in nursing education and practice.

Globally, the WHO (2022) reports that more than 50% of medication errors in children are related to dosage calculation errors, contributing to 14–31% of adverse drug events in pediatric care units. The WHO (2021) also notes that medication errors cause more than 42 million incidents annually, and children are a more vulnerable group due to their high physiological sensitivity. In the Asia region, regional reports indicate that dosing errors account for 12–36% of medication errors, with some studies in teaching hospitals reporting figures ranging from 5–27%. In Indonesia, the Ministry of Health, through its patient safety report, confirms that medication errors rank among the top three most common incidents, with the majority of errors occurring during the calculation and preparation of doses, including for pediatric patients. Short-term effects of dosage calculation errors may include vomiting, adverse drug reactions, acute organ dysfunction, respiratory arrest, or the need for intensive care, while long-term effects include neurological complications, developmental disorders, prolonged hospital stays, disability, and increased mortality risk—particularly in cases of drug overdose involving medications with a narrow therapeutic range (Ministry of Health of the Republic of Indonesia, 2023).

There are various factors contributing to pediatric medication dosing errors. At the individual level, many students and healthcare professionals still struggle with basic mathematical concepts such as unit conversion, weight-based calculations, and selecting the appropriate formula (McMullan, 2018; Valizadeh et al., 2016). Inaccuracies when entering numbers, such as body weight, volume, or drug concentration, are also common triggers, particularly for medications with narrow therapeutic ranges (WHO, 2021). Difficulties in dosage calculations among nursing students have been documented in previous studies. Özyazıcıoğlu et al. (2018) identified difficulties among nursing students in calculating safe pediatric doses, while Wennberg-Capellades et al. (2022) found that only 52.7% of 863 analyzed dosage calculation exercises were answered correctly. These findings highlight the importance of strengthening dosage calculation skills during nursing education. Nursing students are therefore a relevant target population for educational interventions aimed at developing pediatric dosage calculation competencies before they enter professional clinical practice. However, these findings do not establish that nursing students experience higher clinical medication error rates than practicing nurses. At the system level, the use of adult drug formulations that must be diluted to achieve pediatric doses can contribute to errors, especially when clear pediatric dosing guidelines are unavailable (Indonesian Ministry of Health, 2017). Additionally, a busy work environment, high workload, lack of supervision, and time pressure contribute to an increased risk of errors (Suluhan et al., 2023; Puangsuwan et al., 2025). This combination of cognitive and environmental factors makes pediatric dose calculation an area requiring special attention in nursing education.

Various studies have explored approaches to improve nursing students' medication dosage calculation skills, ranging from traditional lectures to digital learning technologies. Nursing students may experience difficulties with basic numeracy, unit conversion, and the application of clinical concepts, which may affect their ability to calculate medication doses accurately (Valizadeh et al., 2016).

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Although face-to-face lectures provide a theoretical foundation, digital learning approaches offer additional opportunities for practice and feedback. E-learning modules, mobile applications, video-based learning, blended learning, and collaborative platforms such as Padlet have been investigated to support dosage calculation skills and learning outcomes (McMullan, 2018; Bıyık Bayram, 2024; Baran & Öztürk, 2025). Visual learning strategies, such as the Triangle Technique, have also been used to help nursing students understand the relationships between dosage variables (Suluhan et al., 2023). Furthermore, screen-based simulation has demonstrated potential for improving students' medication administration and dosage calculation skills, while augmented reality applications have been explored to support pediatric intravenous medication administration (Mahou et al., 2024; Puangsuwan et al., 2025). Instant messaging platforms have also been investigated as tools for microlearning and quizzes (Jaiswal & Rao, 2025; Pourteimour et al., 2019). The interventions described in these studies primarily address learning among nursing students in educational settings, including classroom activities, dosage calculation exercises, and simulation-based practice. This focus is relevant because developing dosage calculation competencies during the academic stage may help prepare students for safer medication administration in future clinical practice. However, the educational stage and setting should be considered individually for each included study, as not all studies necessarily involve the same learning context. Overall, digital learning approaches may support the development of medication dosage calculation skills, although their effectiveness may vary according to the intervention and instructional design.

Although various forms of digital learning have been tested and some have shown positive results, findings across studies remain inconsistent due to differences in design, media types, and the indicators used. Most studies assess improvements in test scores as the primary outcome, while other important aspects—such as the ability to recognize errors, self-efficacy, and clinical readiness in a pediatric context—are rarely evaluated systematically. The variety of media used—ranging from videos, mobile apps, and collaborative platforms to simulations and augmented reality—also makes it difficult to directly compare results. To date, the available evidence has not been systematically synthesized to comprehensively compare the effectiveness of different digital learning approaches in improving nursing students' pediatric medication dosage calculation skills, particularly regarding differences in learning outcomes, assessment indicators, and the extent to which these approaches support the development of calculation accuracy and related competencies.This situation indicates a research gap that requires a more comprehensive review.

Nurses and nursing students play a critical role in ensuring the accuracy of medication dosing for children; however, various factors can increase the risk of errors. Limited knowledge of pharmacology, math anxiety, lack of clinical experience, and reliance on manual calculation methods often lead to incorrect data entry, selection of the wrong formula, or incorrect unit conversion. In clinical practice, time pressure, multitasking, and high workloads often exacerbate the situation, making students who have not mastered basic concepts or are not yet accustomed to the complexities of pediatric dosing more prone to misinterpreting dosing instructions. These findings are consistent with various studies highlighting the relationship between math anxiety, low self-confidence, and students' calculation abilities in the context of pediatric medication administration (Sayadi et al., 2021).

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Based on various previous studies, it appears that conventional methods such as manual calculations, the use of simple calculators, and lecture-based learning tend to have weaknesses in the form of the risk of human error, dependence on individual numerical ability, and limitations in visualization. Meanwhile, digital methods offer higher accuracy, consistency in calculations, simulation capabilities, reduced cognitive load, and learning flexibility (McMullan, 2018; Mahou et al., 2024). Students can also learn at their own pace. Nevertheless, the success of digital methods still depends on the application design, content quality, and students' ability to use them consistently.

Given this urgency, the researchers conducted a Systematic Literature Review (SLR) on the topic "Digital Learning Methods to Improve Nursing Students' Skills in Pediatric Drug Dosage Calculations." Through this SLR, it is hoped that a comprehensive understanding of the effectiveness of digital educational media can be presented, thereby supporting the development of innovative approaches to pediatric drug dose calculation in nursing education institutions and providing a solid foundation for further research.

## METHOD

This study employed a systematic literature review design based on the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This approach was used to identify, select, evaluate, and synthesize empirical evidence regarding the effectiveness of digital-based learning methods on nursing students' ability to calculate pediatric drug doses.

The design of this literature search began with formulating the PICO (Population, Intervention, Comparison, Outcomes) framework, structured as follows: P (Population): Nursing students; I (Intervention): Digital learning methods (e.g., mobile apps, digital simulations, e-learning), C (Comparison): Conventional learning methods (e.g., face-to-face learning, textbooks, manual methods), O (Outcome): Students' ability to calculate pediatric drug doses (measured through tests or dose calculation skill assessments).

### Research Question (RQ)

"How effective is a digital-based learning method compared to conventional learning methods in improving nursing students' ability to calculate pediatric drug doses?"

### Data Sources and Search Strategy

The literature search was conducted through a number of reputable international scientific databases, including: Scopus, PubMed, SAGE Journals, ScienceDirect, EBSCOhost, Cochrane Library, Taylor & Francis, and ProQuest. The search was performed using a combination of keywords with Boolean operators: Digital Learning OR Simulation OR Teaching Methods AND Medication dosage calculation OR Drug dosage calculation AND Nursing students AND Pediatric.

### Inclusion and Exclusion Criteria

The inclusion criteria were studies involving nursing students that examined digital learning interventions for pediatric medication dosage calculation, used randomized controlled trial (RCT) or quasi-experimental designs, and were published in English between 2015 and 2025. Studies were required to assess

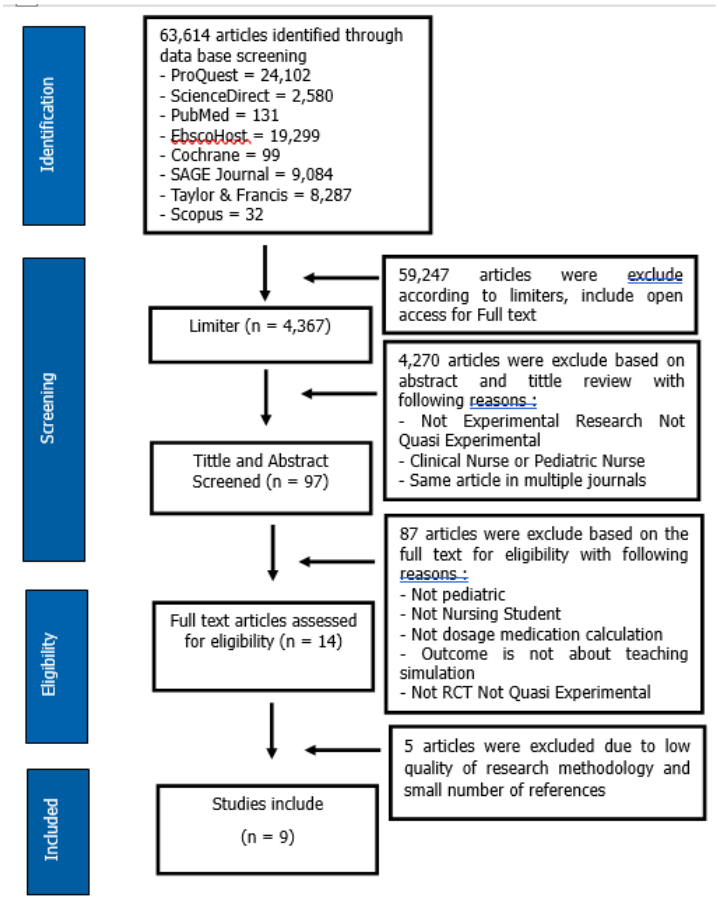
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students' pediatric medication dosage calculation skills. The exclusion criteria were articles that were inaccessible, not quasi-experimental or RCTs (Randomized Controlled Trials), irrelevant to the topic, or for which the full text was unavailable.

## Study Selection Process and Data Extraction Process

The article selection process follows the four main stages of the PRISMA 2020 flowchart, namely: Identification: All articles identified from various databases were collected and compiled into a preliminary list; Screening: Duplicates were removed, and titles and abstracts were reviewed to assess compliance with the inclusion criteria; Eligibility: Full-text articles that pass the screening stage are examined in greater depth to ensure their relevance and suitability; and Inclusion: Articles that meet all criteria are included in the final analysis and synthesis process. Data extraction was performed using a predefined table, covering the following components: authors and year of publication, study design, sample size and characteristics, type of digital intervention, comparison group (if any), evaluation instruments, primary outcomes, and study limitations.

**Figure 1. PRISMA Diagram**




## Quality Assessment of Articles

The quality of the articles was assessed using the Joanna Briggs Institute (JBI) checklist for quasi-experimental studies and the checklist for randomized controlled trials. The JBI questionnaire contains several questions to assess the quality of the studies used, with respondents answering "yes," "no," "unclear," or "not applicable" for each item.

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Critical Appraisal of Randomized Controlled Trials (RCTs)

Article 1 : Bahar, A., et al. (2017). Do Parenteral Medication Administration Skills of Nursing Students Increase with Educational Videos Materials?

Article 2 : Manuela, F., et al. (2019). Effectiveness of E-Learning Training on Drug – Dosage Calculation Skills of Nursing Students: A Randomized Controlled Trial

**Table 1. Critical Appraisal Artikel Case Randomized Controlled Trials**

| No | Item | Article Quality Assessment | |
|---|---|---|---|
| | | **1** | **2** |
| 1 | *Was true randomization used for assignment of participants to treatment groups?* | Y | Y |
| 2 | *Was allocation to treatment groups concealed?* | U | U |
| 3 | *Were treatment groups similar at baseline?* | Y | Y |
| 4 | *Were participants blind to treatment assignment?* | N | N |
| 5 | *Were those delivering treatment blind to treatment assignment?* | N | N |
| 6 | *Were outcome assessors blind to treatment assignment?* | Y | U |
| 7 | *Were treatment groups treated identically other than the intervention of interest?* | Y | Y |
| 8 | *Was follow up complete and if not, were differences between groups described and analyzed?* | U | U |
| 9 | *Were participants analyzed in the groups to which they were randomized (intention-to-treat)?* | U | Y |
| 10 | *Were outcomes measured in the same way for treatment groups?* | Y | Y |
| 11 | *Were outcomes measured reliably?* | Y | Y |
| 12 | *Was appropriate statistical analysis used?* | Y | Y |
| 13 | *Was the trial design appropriate, and any deviations from the standard RCT design accounted for?* | Y | Y |
| | **Percentage** | **62%** | **62%** |
| | **Results** | **Include** | **Include** |

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Critical Appraisal of Quasi-Experimental Studies

Article 3 : Jaiswal, V. K., & Rao, V. S. (2024). Smartphone-based application for preventing medication errors among pediatric nurses

Article 4 : Valizadeh, S., et al. (2016). Effect of Education of Principles of Drug Prescription and Calculation through Lecture and Designed Multimedia Software on Nursing Students' Learning Outcomes.

Article 5 : Baran, L., Öztürk, H. (2025). The effects of video-based and blended learning on medication dosage calculation skills of paramedic students.

Article 6 : Pourteimour, S., et al. (2019). The Effect of Smartphone-Based Application Learning on the Nursing Students' Performance in Preventing Medication Errors in the Pediatric Units.

Article 7 : McMullan, M. 2018. Evaluation of a medication calculation mobile app using a cognitive load instructional design.

Article 8 : Bayram, B. Ş. (2024). The Effect of Padlet on Nursing Students' Drug Dose Calculation Skills.

Article 9 : Yiin, S. J., & Chern, C. L. (2023). The effects of an active learning mechanism on cognitive load and learning achievement: A new approach for pharmacology teaching to Taiwanese nursing students.

**Table 2. Critical Appraisal of Quasi-Experimental Studies**

| No | Item | Article Quality Assessment | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| 1 | *Is it clear in the study what is the cause and what is the effect?* | Y | Y | Y | Y | Y | Y | Y |
| 2 | *Were the participants included in any comparisons similar?* | Y | Y | Y | Y | N/A (single group) | Y | Y |
| 3 | *Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?* | Y | Y | Y | Y | N | Y | Y |
| 4 | *Was there a control group?* | Y | Y | Y | Y | N | N | Y |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | *Were there multiple measurements of the outcome both pre and post the intervention/exposure?* | Y | Y | Y | Y | Y | Y | Y |
| 6 | *Was follow up complete and if not, were differences between groups in terms of their follow up described and analyzed?* | U | U | Y (short-term) | Y | Y | N/A (single group) | Y |
| 7 | *Were the outcomes measured in a reliable way?* | Y | Y | Y | Y | Y | Y | Y |
| 8 | *Was appropriate statistical analysis used?* | Y | Y | Y | Y | Y | Y | Y |
| 9 | *Was the design appropriate to answer the research question?* | Y | Y | Y | Y | Y | Y | Y |
| **Percentage** | | **89%** | **89%** | **100 %** | **100 %** | **67%** | **78%** | **100 %** |
| **Result** | | **Include** | **Include** | **Include** | **Include** | **Include** | **Include** | **Include** |

**Description:**
Y = Yes
N = No
UN = Uncler
NA = Not Applicable

## RESULTS AND DISCUSSION

The article selection process was conducted in accordance with the PRISMA 2020 Flow Diagram, comprising four stages: Identification: 63,614 articles were retrieved from all databases. Screening: 59,247 articles were eliminated for failing to meet initial criteria (not open access, not full text, or irrelevant). Eligibility: 14 articles were read in full, and 5 of them were excluded due to low methodological quality. Inclusion: 9 articles meeting the criteria were included in the final analysis. Exclusion criteria included: non-experimental studies, respondents who were not nursing students, non-pediatric contexts, or outcomes other than the ability to calculate drug doses.

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Data from each article that passed the selection process were extracted using a tabular format that included: authors and year of publication, study design, sample size and characteristics, type of digital intervention, comparison group (if any), evaluation instruments, primary outcomes, and study limitations. Data extraction was performed manually by two researchers working independently, and the results were then compared to ensure consistency. Discrepancies were resolved through joint discussion; details can be found in the summary of the articles compiled in Table 3 below.

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| Article Title, Author, and Year of Publication | Type of Intervention | Research Design, Sample, and Sampling Method | Control Group | Evaluation Instruments | Research Findings | Limitations of the Study |
|---|---|---|---|---|---|---|
| Bahar et al. (2017) | Educational video on parenteral medication administration | RCT, n=80, simple random sampling | Conventional demonstration | Questionnaire & OSCE Higher | Higher OSCE scores in the video group | Single institution, limited generalizability |
| Manuela et al. (2019) | E-learning | RCT, n=198, simple random sampling | Face-to-face | Dose-dependent test (pre-post) | Not more effective than traditional methods | Short duration, no follow-up |
| Jaiswal & Rao (2024) | Smartphone app (Telegram) | Quasi eksperimen, n=85 simple random sampling | Standard training | Checklist | Improving understanding of medication errors | Small sample |
| Valizadeh et al. (2016) | Multimedia vs lecture | Quasi eksperimen, n=85 simple random sampling | lecture | Dosage questionnaire | Multimedia is more effective | Limited generalizability |
| Baran & Öztürk (2025) | Video vs blended learning | Quasi eksperimen, n=151 Random sampling | Only Video | Medication Dose Calculation Skills Test (MDCST) | Blended learning is more effective | E-learning is not yet optimal |
| Pourteimour et al. (2019) | Telegram App | Quasi eksperimen, n=80 Random sampling | Regular learning | Checklist | Expanding knowledge | Limited sample |
| McMullan (2018) | Mobile App | One-group quasi, n=60 *Convenience sampling* | Conventional | Drug Dosage Calculation & Self-Efficacy Test | Improve skills & confidence | No control group |
| Bayram (2024) | Padlet | One-group pre-post, n=42 | None | DDCKT | Increased dosage | No control group |
| Yiin & Chern (2023) | Active learning multimedia | True experiment, n=188 | Conventional | Testing & cognitive load | Improving understanding | Limited locations |

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A synthesis of 9 articles indicates that the teaching methods used to improve nursing students' ability to calculate pediatric drug doses are highly diverse and dominated by digital-based approaches. These methods include video-based learning combined with clinical demonstrations (Bahar et al., 2017), online platform-based e-learning (Manuela et al., 2019), smartphone-based instant messaging apps such as Telegram (Jaiswal & Rao, 2025; Pourteimour et al., 2019), interactive multimedia software (Valizadeh et al., 2016), blended learning integrating online and face-to-face learning (Baran & Öztürk, 2025), mobile applications based on cognitive load instructional design (McMullan, 2018), Web 2.0-based collaborative platforms such as Padlet (Bayram, 2024), and interactive multimedia-based active learning mechanisms (Yiin & Chern, 2023). Most studies reported improvements in dosage calculation accuracy, conceptual understanding, and students' self-efficacy in the context of pediatric medication administration.

The duration of the interventions administered in each learning method showed considerable variation. Educational video-based interventions were conducted over a short learning period integrated into clinical practice sessions (Bahar et al., 2017). E-learning was implemented over a relatively short duration without long-term follow-up (Manuela et al., 2019). Telegram-based interventions lasted for several weeks with structured learning periods (Pourteimour et al., 2019; Jaiswal & Rao, 2025). Multimedia software and blended learning were provided over several weeks within a single academic learning cycle (Valizadeh et al., 2016; Baran & Öztürk, 2025). A cognitive load-based mobile app was evaluated through its use over a single semester-long learning period (McMullan, 2018). Padlet was used during a series of learning sessions within a single module (Bayram, 2024), while multimedia active learning was implemented in a single structured pharmacology learning unit (Yiin & Chern, 2023). Generally, most interventions lasted between one and several weeks within a single learning cycle.

The frequency of use of learning methods also varies depending on the design of each study. Video-based learning is generally used once or played several times prior to the OSCE evaluation (Bahar et al., 2017). E-learning is accessed as needed by students during the intervention period, with pre–post test evaluations (Manuela et al., 2019). Telegram is used periodically to send materials, quizzes, and facilitate routine discussions during the intervention period (Pourteimour et al., 2019; Jaiswal & Rao, 2025). Multimedia software and mobile applications allow for repeated use and unlimited self-directed practice throughout the study period (Valizadeh et al., 2016; McMullan, 2018). Blended learning involves a combination of online sessions and several facilitated in-person meetings (Baran & Öztürk, 2025). Padlet was used interactively during several discussion sessions (Bayram, 2024), while multimedia active learning was used during several sessions within a single learning module (Yiin & Chern, 2023). Overall, methods that allow for repeated access and self-directed practice show a higher frequency of use compared to single-session methods, which contributes to greater consistency in learning outcomes.

The results of this systematic review indicate that all learning methods—whether digital-based or a combination of digital and in-person—improve nursing students' ability to calculate pediatric drug doses. Rationally, these findings can be explained through cognitive load theory, self-regulated learning, and the principles of active learning, which emphasize the importance of repeated practice, immediate feedback, and structured presentation of material in enhancing clinical numeracy skills. Pediatric dose calculation is a complex skill involving unit

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conversion, formula selection, and the integration of clinical data such as body weight and drug concentration. Therefore, learning methods that simplify information, reduce cognitive load, and provide consistent opportunities for repeated practice tend to yield more significant improvements.

Video-based learning methods demonstrate improved skills because visual presentations and demonstrations of procedural steps help students understand the calculation process systematically (Bahar et al., 2017). Theoretically, procedural visualization supports the encoding of information into long-term memory and reduces errors caused by misconceptions. However, its effectiveness is more limited compared to interactive methods because students tend to act as passive recipients. This explains why video-only results are not always superior to methods involving active practice.

Platform-based e-learning methods do not always yield results superior to traditional learning (Manuela et al., 2019). The effectiveness of e-learning depends heavily on instructional design and the level of student engagement. Without interactive components, real-time feedback, or structured exercises, e-learning can become merely a digitization of conventional lectures. Therefore, the short duration and lack of practice reinforcement in the study likely limited the impact on skill improvement.

In contrast, mobile learning and smartphone-based apps have shown more consistent improvements (McMullan, 2018; Pourteimour et al., 2019; Jaiswal & Rao, 2025). This is evident in the flexibility of access, high frequency of practice, and the application of microlearning principles. Students can review material, take short quizzes, and receive feedback at any time, thereby reinforcing memory through distributed practice. Additionally, cognitive load-based design in apps (McMullan, 2018) helps simplify calculation processes with clear step-by-step structures, thereby reducing extrinsic cognitive load and improving accuracy.

Blended learning methods demonstrate more consistent results compared to standalone video or e-learning (Baran & Öztürk, 2025). Blended learning integrates the strengths of digital learning (flexibility and repetition) with face-to-face learning (immediate clarification, discussion, and facilitated practice). This combination supports constructivist learning, where students build understanding through interaction and reflection. Another rationale is the opportunity to correct errors before they become permanent misconceptions.

Collaborative platforms such as Padlet show improvement because they encourage social and reflective learning (Bayram, 2024). Discussions and comparisons of answers among students reinforce cognitive elaboration and correct errors through peer feedback. This aligns with social constructivism theory, which states that knowledge is constructed through social interaction.

Meanwhile, an active learning mechanism based on interactive multimedia (Yiin & Chern, 2023) is effective because it engages students in quizzes, immediate feedback, and motivational elements. This approach increases engagement and facilitates retrieval practice, which has been empirically proven to improve long-term retention.

Overall, the primary reasons why digital methods yield positive results are that they enable repeated practice (repetition and distributed practice), provide immediate feedback, reduce cognitive load through visualization and clear step-by-step structures, boost self-efficacy and reduce math anxiety, and encourage active and collaborative engagement.

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Methods that are one-way or very short-lived tend to show more limited improvement. Conversely, methods with high frequency of use and a combination of facilitated practice yield more stable and consistent results. Thus, theoretical and empirical evidence indicates that the effectiveness of digital learning in the context of pediatric dose calculation is significantly influenced by instructional design, frequency of practice, integration of clinical practice, and continuous feedback support.

This systematic review has several limitations that must be considered when interpreting the results. First, most of the reviewed studies used quasi-experimental designs, and only two studies employed a randomized controlled trial design (Bahar et al., 2017; Manuela et al., 2019); consequently, the methodological strength of the evidence remains limited and may be subject to selection bias or internal bias. Second, the majority of studies were conducted at a single institution with relatively small sample sizes, so generalizing the findings to a broader and cross-national population of nursing students must be done with caution. Third, there is significant heterogeneity in the types of interventions, duration of implementation, frequency of use, and evaluation instruments employed, making it impossible to conduct a quantitative meta-analysis to statistically calculate effect sizes and directly compare the effectiveness of different methods. Fourth, most studies only evaluated short-term outcomes through pre–post tests without longitudinal follow-up, so the retention of skills and their impact on actual clinical practice cannot yet be confirmed. Fifth, the article selection process was limited to English-language publications from 2015 to 2025, potentially introducing publication bias and language bias, with the risk of excluding relevant studies in other languages or from earlier periods. Additionally, article quality assessment was conducted using the Joanna Briggs Institute checklist without reporting inter-rater reliability, which may affect the objectivity of the appraisal process. Therefore, although the results of this review indicate a consistent improvement in dose calculation ability through digital methods, the interpretation of conclusions must still account for methodological limitations and variations in the characteristics of the reviewed studies.

## CONCLUSIONS AND RECOMMENDATIONS

The results of this systematic review indicate that digital-based learning methods, such as blended learning, mobile learning, video-based learning, and interactive digital platforms, can improve nursing students' ability to calculate pediatric medication doses. Most studies reported improvements in outcomes related to dosage calculation skills, although the effectiveness of these approaches varied across studies. Compared with conventional methods, digital approaches offer potential advantages in terms of learning flexibility and opportunities for repeated practice. However, e-learning was not found to be more effective than traditional learning methods in the study by Manuela et al. (2019).

Several limitations were identified in the reviewed studies, including the predominance of quasi-experimental designs, the use of relatively small samples limited to a single institution, and the lack of long-term evaluation of skill retention. Additionally, variations in measurement instruments and the types of digital interventions used led to heterogeneity in the results, thereby limiting the generalizability of the findings.

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Therefore, future research is recommended to use randomized controlled trial designs with larger sample sizes and participants from multiple institutions to enhance external validity. Additionally, standardization of evaluation instruments and long-term follow-up measurements are needed to assess the sustainability of the effects of digital interventions on dosage calculation skills. Research should also examine the relationship between improvements in these skills and reductions in medication errors in real-world clinical practice.

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