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Online Flipped Classroom Models in Surgical and Procedural Education: A Systematic Search and Narrative Synthesis

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Abstract

Background: The growing demand for innovative, learner-centered approaches in health professions education has led to increasing adoption of the flipped classroom (FC) model. Surgical and procedural education present unique pedagogical challenges, requiring the integration of foundational knowledge, clinical reasoning, spatial understanding, decision-making, and technical skills. The transition toward online and technology-enhanced learning environments has further highlighted the need for instructional models that support these diverse educational outcomes while maintaining learner engagement and educational quality. Although online flipped classroom approaches have gained increasing attention in surgical and procedural training, a comprehensive synthesis of the available evidence regarding their effectiveness, opportunities, and challenges remains limited.

Objectives: This review aimed to synthesize the current evidence regarding the role of online flipped classroom models in surgical and procedural education and to examine their impact on learning outcomes, learner engagement, satisfaction, and procedural skill development.

Methods: This systematic review with narrative synthesis design examined 35 peer-reviewed articles published between 2019 and 2026, retrieved from PubMed, Scopus, and ScienceDirect. Sources encompass qualitative, quantitative, and mixed-method studies, including randomized controlled trials and quasi-experimental designs, focusing on the efficacy of the online flipped classroom in surgical education. Data extraction followed a standardized PRISMA-based checklist, while methodological quality was rigorously appraised using JBI critical appraisal tools.

Result: Analysis of the 35 included studies identified four recurring thematic domains: (1) Learning outcomes and educational effectiveness, (2) Student and faculty satisfaction, perceptions, and engagement, (3) Technological and multimodal integration, and (4) Methodological and curricular comparisons. Across studies, the online flipped classroom was consistently associated with improved academic performance, knowledge retention, conceptual understanding, clinical reasoning, and procedural skill acquisition. High levels of learner engagement, satisfaction, confidence, and preference for the flipped approach were frequently reported. Digital tools, including mobile applications, video-assisted learning, MOOCs, SPOCs, simulation-based activities, and blended learning environments, enhanced educational flexibility and supported continuity of surgical training. While most studies demonstrated favorable outcomes compared with traditional lecture-based instruction, some reported comparable academic performance. Evidence was concentrated in ophthalmology and general surgery, whereas several complex surgical subspecialties remained underrepresented. Additional challenges included increased faculty preparation time, variability in implementation strategies, and limited evidence regarding long-term educational sustainability.

Conclusion: The available evidence suggests that the online flipped classroom is a promising educational approach for surgical education, contributing to improved learning outcomes, procedural competence, clinical reasoning, and learner engagement. The integration of technology-enhanced learning tools further supports flexible, learner-centered, and scalable surgical training. Based on the

synthesized evidence, a four-domain conceptual framework encompassing educational effectiveness, learner engagement, technological integration, and curricular implementation may guide future adoption and evaluation of online flipped classroom models. Nevertheless, the predominance of quasi-experimental designs, limited longitudinal evidence, and underrepresentation of several surgical specialties highlight the need for rigorous, context-sensitive research to establish the long-term effectiveness and sustainability of this educational approach.

Introduction

Today, online learning is acknowledged as a powerful tool in modern education, contributing to significant changes in both learning and teaching methodologies (1). According to a report by Statista, the number of online learning users worldwide increased from 300 million in 2010 to over 1.5 billion in 2021 (2). In the demanding field of medical education, characterized by a high volume of specialized courses and abstract concepts, online learning systems offer a promising solution. They foster a constructivist, learner-centered approach, which is particularly suitable for complex disciplines like surgery (3). Medical education faces significant challenges, including time and location constraints, limited access to equipment and practical cases, and the abstract nature of many core concepts. These factors collectively hinder the effective development of knowledge and skills among students. Furthermore, as technology advances, students' educational expectations have evolved, creating a demand for more dynamic, flexible, and high-quality methods than those offered by traditional, often unengaging, curricula.

In response to these challenges, the flipped classroom model has emerged as a key innovation (4–6). Grounded in constructivist learning theory, which emphasizes that students actively construct knowledge through experience and reflection (18), this approach significantly enhances the flexibility of teaching and transforms the learner's role from passive to active. Consequently, learners gain greater access to resources and numerous opportunities to participate and engage in the learning process. This theoretical foundation makes it particularly suitable for complex surgical disciplines that demand both cognitive and procedural integration. (7). The online flipped classroom model comprehensively encompasses the entire learning process, from pre-class preparation to online course activities. This model effectively addresses the learning barriers posed by the physical environment, making it superior to traditional flipped classrooms. Additionally, it helps to diminish the sense of distance in online education and enhances interactions between the instructor and the learner (8). The results of a study have shown that the online approach in a flipped classroom enhances participation, fosters sufficient interaction between learners and instructors in distance education, and improves the overall learning process (9). Also, Galway et al. (2024) recognize that the integration of the flipped classroom model with online courses is an effective innovation that can enhance self-perceived knowledge (10). In general, the use of reverse learning, which involves providing engaging electronic content and opportunities, is positively associated with the development of cognitive skills (11). This method can be applied to courses such as surgery, which demand precision and critical thinking. A study by Lu and Hugh (2022) emphasizes that flipped classrooms can promote active learning and enhance higher-order thinking

skills (12). This is especially important for mastering complex subjects such as surgery. The implementation of the flipped classroom model in surgical education has shown promising results. In this context, Parker et al. (2022) described a modular online curriculum designed for surgical trainees in East, Central, and Southern Africa that employed flipped classroom principles to address gaps in surgical knowledge and enhance educational outcomes. They found that this approach not only facilitates a better understanding of surgical procedures but also promotes collaborative learning among trainees (13). The results of another study indicate that the flipped classroom model can be effectively implemented in head and neck surgery curricula. Residents have demonstrated a strong understanding of the importance of engaging with the lesson material prior to class, which enables them to actively participate in the learning process (14). This aligns with the findings of other studies, which demonstrate that online flipped classrooms can effectively deliver complex content in oral and maxillofacial surgery courses while accommodating diverse learning styles and preferences (15). Other evidence has demonstrated that the flipped classroom model has resulted in improved scores on the American Board of Surgery exam for general surgery residents (16).

However, despite this promising evidence, the reported effects are notably variable, suggesting that the model's success is highly context-dependent and influenced by implementation strategies. Moreover, while broader reviews have addressed flipped classrooms in general clinical education, the literature on the application of the online flipped classroom model in surgical education remains diverse and somewhat fragmented. The variability in reported effects indicates that its success is highly dependent on context and implementation strategies. A comprehensive synthesis is needed to consolidate existing findings and clearly determine the model's overall impact on the core objective of medical training: fostering a deep understanding of complex surgical concepts.

While broader reviews cover flipped classroom in general clinical medical education (17) focused narrative synthesis exists for online flipped models targeting undergraduate comprehension of complex surgical concepts such as suturing techniques or operative planning. The flipped classroom model aligns with constructivist learning theory, which emphasizes that students actively construct their own knowledge through experiences, reflection, and interaction rather than passive reception of information. This theoretical foundation supports its application in complex fields requiring active engagement, such as surgical concept comprehension (18).

Despite growing evidence supporting flipped classroom approaches in medical education, there remains a lack of focused synthesis on how online flipped classroom models specifically influence the acquisition and comprehension of complex surgical concepts, which require simultaneous cognitive, procedural, and decision-making integration.

This review aimed to address the following research question:

What are the educational outcomes, opportunities, and challenges associated with the implementation of online flipped classroom models in surgical and procedural education compared with traditional or alternative instructional approaches?

Methods

Study Design

This study employs a narrative synthesis approach to examine the educational outcomes, opportunities, and challenges associated with implementing online flipped classroom models in surgical and procedural education. Narrative synthesis is a structured review method that enables the integration and interpretation of findings from studies with diverse methodological designs, including quantitative, qualitative, and mixed-methods research. This approach is particularly suitable for complex educational interventions, as it facilitates the exploration of how different implementation strategies influence learning outcomes across varied educational contexts. To ensure a comprehensive and contemporary evidence base, this review includes studies published from 2019 to 2026, enabling analysis of recent developments in online and blended learning approaches in surgical education, particularly capturing the full spectrum of post-pandemic pedagogical transformations in medical teaching and learning practices.

Search Strategy

A systematic literature search was conducted to identify studies examining the effectiveness of the online flipped classroom model in enhancing medical students' understanding of complex surgical concepts. The search focused on studies evaluating the implementation, effectiveness, and educational outcomes of online flipped classroom approaches in surgical education and related medical training contexts. Three major electronic databases, including PubMed, Scopus, and ScienceDirect, were systematically searched for relevant articles published between 2019 and 2026. A combination of Medical Subject Headings (MeSH) terms and free-text keywords was used to ensure a comprehensive retrieval of relevant studies. Boolean operators (AND/OR) were applied to refine and optimize the search strategy.

To ensure comprehensiveness, additional relevant studies were identified through manual screening of the reference lists of included articles. The search strategy was structured based on the PICO framework (Population, Intervention, Comparison, Outcome) to enhance conceptual clarity and coverage of relevant literature. For the "Comparison" component, the terms were broadened beyond traditional teaching to include other active learning methods, ensuring a more inclusive retrieval of comparative studies. Details of the search terms, keywords, and Boolean combinations are presented in Table 1.

Table1: MeSH terms and Keywords

PICO (s)	Keyword/MeSH	Combine Search
Population	"Medical students" OR "Undergraduate medical education"	("Medical students" OR "Undergraduate medical education")
Intervention	" "Flipped classroom" OR "Online flipped classroom" OR "OFC" OR "Flipped learning"	("Flipped classroom" OR "Online flipped classroom" OR "Flipped learning")
Comparison	"Traditional teaching" OR "Lecture-based learning" OR "Conventional teaching"	("Traditional teaching" OR "Lecture-based learning")
Outcome	"Learning outcomes" OR "Knowledge retention" OR "Clinical reasoning" OR "Educational effectiveness"	("Learning outcomes" OR "Knowledge retention" OR "Clinical reasoning" OR "Effectiveness")

Study Selection

Rigorous inclusion and exclusion criteria were implemented to ensure the relevance and methodological quality of the selected studies. Publications were included if they explicitly examined the impact of the flipped classroom and online flipped classroom model on the acquisition and understanding of complex surgical concepts among medical students.

Eligible publications comprised peer-reviewed qualitative, quantitative, and experimental studies. To maintain academic rigor, editorials, books, theses, and non-peer-reviewed materials were excluded. Only articles published in English between 2019 and 2026 were considered to ensure both recency and the integration of the latest digital pedagogical advancements.

The selection process followed a two-stage methodology: an initial screening of titles and abstracts for relevance, followed by a comprehensive full-text evaluation of potentially eligible studies. Articles that did not meet the predefined inclusion criteria were excluded after a thorough full-text assessment. To provide full transparency and adhere to PRISMA guidelines, the detailed numbers for this screening process are reported in the text. The initial database searches yielded 487 records. After removing 269 duplicates and clearly irrelevant titles, 218 records were screened based on titles and abstracts. Of these, 165 records were excluded, and the remaining 53 full-text articles were assessed for eligibility. Following full-text evaluation, 18 articles were excluded for reasons including lack of explicit focus on surgical concepts, absence of an online flipped classroom intervention, or non-empirical designs. Finally, 35 studies met the predefined inclusion criteria and were included in the narrative synthesis. This process ensured that the review captures a robust body of empirical evidence and scholarly insights into the efficacy of flipped learning within the surgical domain (see Table 2).

Table2: Inclusion and exclusion criteria

Criteria Type	Inclusion Criteria	Exclusion Criteria
Study Relevance	Articles explicitly investigating the influence of online flipped classroom models on the learning and mastery of complex surgical concepts.	Articles that do not address the flipped classroom model or those focusing on general medical education without a specific link to surgical concepts. |
Study Design	Peer-reviewed qualitative, quantitative, and experimental studies providing empirical data on educational outcomes.	Editorials, books, theses, dissertations, and letters to the editor lacking scholarly justification.
Quality Assurance	Full-text peer-reviewed articles to ensure the validity and reliability of the reported information.	Non-peer-reviewed articles, studies lacking rigorous methodology or scientific scrutiny, and abstracts only.
Screening Process	Articles published between 2019 and 2026, screened through a two-stage process (title/abstract and full-text review).	Articles were excluded after full-text assessment if they failed to meet the predefined inclusion criteria or lacked a clear link to surgical education.

Data Extraction

Data extraction was conducted independently by three reviewers to enhance reliability and minimize bias. The reviewers systematically recorded study characteristics using a structured extraction tool based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist, ensuring consistency and comprehensiveness across all included studies.

The extraction process captured key elements of each study, including title, author(s), year of publication, study objectives, methodological approach, population and setting, the specific structural components of the online flipped classroom model, the nature of the surgical concepts addressed, and the principal educational outcomes.

This approach enabled a standardized synthesis of information while facilitating a comparative analysis across studies, highlighting pedagogical patterns, discrepancies, and gaps in the literature regarding the effectiveness of flipped learning in surgical education (Figure 1).

Quality assessment process

To ensure methodological rigor, we conducted a thorough quality appraisal of the included studies through a structured, multi-step evaluation process.

1. Selection of Assessment Tools: We selected the Joanna Briggs Institute (JBI) Critical Appraisal Checklists to evaluate the methodological quality of the included studies. Given the diversity of study designs represented in the review, the appropriate JBI checklist was applied according to the specific methodological characteristics of each study. The JBI appraisal tools are widely recognized in health

sciences and medical education research and provide structured criteria for assessing methodological rigor, risk of bias, and reporting quality. Their use facilitated a systematic and transparent evaluation of the included evidence.

2. Assessment Criteria: The assessment criteria included:

JBI Checklists: Depending on the specific study design (e.g., RCTs, quasi-experimental, or qualitative), these checklists assessed components such as the congruity between research objectives and methodology, sampling appropriateness, data collection methods, analysis transparency, and the validity of the conclusions drawn from the data.

3. Process of Evaluation: Each included study was independently appraised by two reviewers to ensure objectivity and minimize potential bias. Discrepancies in scoring or interpretation were resolved through discussion, and if needed, a third reviewer was consulted to reach consensus. Appraisals were conducted using the scoring system and criteria embedded within the JBI tool. This process allowed for a consistent and transparent evaluation of each study's methodological rigor.

4. Handling of Low-Quality Studies: Most included studies demonstrated moderate to good methodological quality. A small number of studies exhibited certain limitations (e.g., small sample sizes or non-randomized designs); however, none were deemed so severely flawed as to warrant complete exclusion from the synthesis. Instead, these studies were carefully reviewed, and their findings were interpreted with appropriate caution. Their influence on the overall conclusions was qualitatively weighed against the more robust evidence, ensuring that our final synthesis reflects the balance of available evidence.

5. Reporting Findings: Quality assessment results were thoroughly incorporated into the review, with a dedicated summary table showcasing the methodological robustness of each study and guiding readers in evaluating the credibility of the synthesized evidence. This structured quality appraisal also informed the robustness assessment stage of our narrative synthesis framework.

6. Publication Bias: Formal statistical assessment of publication bias (e.g., via funnel plots or Egger's test) was not performed due to the substantial clinical and methodological heterogeneity across the included studies, as well as the predominantly narrative nature of the synthesized evidence.

7. Implications for Future Research: Conducting this structured quality assessment enhanced the transparency of our review and provided critical insights into the current state of research on online flipped classrooms in surgical education. The observed methodological gaps, such as limited reporting of long-term educational outcomes or lack of standardized assessment tools for surgical concepts, highlight significant areas for improvement. Future studies in this domain would benefit from stronger alignment with established appraisal standards, more rigorous experimental designs, and clearer reporting of pedagogical interventions.

Result

Table 3 presents a comprehensive summary of recent studies examining the effectiveness and impact of the online flipped classroom model in surgical education. In this review, a total of (35) articles were identified through a systematic search of the literature. The included studies encompass qualitative research, quantitative assessments, and experimental and quasi-experimental designs reflecting the methodological diversity of this field.

By synthesizing findings across these various investigations, this review provides insights into how this innovative pedagogical approach influences learning outcomes and student experiences within surgical disciplines, ultimately informing the integration of digital learning strategies in medical curricula (Please see Table 3).

Table3. Summary of the reviewed studies

lication r	Title	Goal	Methodology	Feild	Findings
9	Flipped classroom as an effective educational tool in teaching surgery for undergraduate students	To determine if the flipped classroom is an effective tool for teaching surgery to undergraduate medical students compared to traditional methods	Quasi-experimental Study	Surgical education	The effectiveness of the flipped class on creating motivation, improving course materials, improving communication skills, and clinical thinking
0	Flipping the Classroom in Otolaryngology Residencies	To understand program directors' attitudes and current/future use of flipped classroom in otolaryngology residency programs	Cross-sectional Study	Otolaryngology	The existence of a positive attitude and perception towards the principles of the flipped classroom model among otolaryngology residency students and also
0	The effect of case-based teaching and flipped classroom methods in comparison with the lecture method on learning and satisfaction of internship students in surgery	To determine the effect of case-based teaching and flipped classroom vs lecture on learning outcomes and satisfaction of internship students in general surgery	Quasi-experimental Study	Surgery internship	The effectiveness of the flipped classroom in increasing learning and students' satisfaction with the lecture method
0	Comparative analysis of effectiveness between flipped classroom and lecture-based classroom in undergraduate medical education at Alfaisal University	To compare the effectiveness of flipped classroom and traditional lecture-based classroom in undergraduate medical education through academic performance	Quasi-experimental Study	General surgery & neurosciences	Ineffectiveness of flipped classroom in general surgery Students No statistically significant difference between the flipped

					classroom method and lecture
:1	Effectiveness of flipped classroom model in teaching histology for first-year MBBS students based on competency-based blended learning: An interventional study	To evaluate the effectiveness of the flipped classroom model compared to traditional lectures in histology sessions based on competency-based blended learning	Quasi-experimental Study	Histology	The effectiveness of the reverse teaching method in histology course and increasing the knowledge of students surgery
:1	Using the flipped classroom model in surgical education: efficacy and trainee perception.	To assess efficacy, performance improvement, and trainee perception of the flipped classroom model in surgical education conferences	Quasi-experimental Study	Surgical education	Adoption of the flipped classroom by surgical trainees due to its effectiveness in preparing the learner before the start of the exam and teaching conferences
:1	The Impact of Flipped Learning in Surgical Education: A Mixed-Method Study.	To investigate the impact of flipped learning on knowledge acquisition satisfaction and perceptions in surgical education	Mixed-methods Study	Surgical education	The effectiveness of reverse learning in the acquisition and retention of knowledge in trauma

:1	Development of a tailor-made surgical online learning platform, ensuring surgical education in times of the COVID19 pandemic	To develop and implement a tailor-made surgical online learning platform to ensure continued surgical education during the COVID-19 pandemic	Randomized Controlled Trial (RCT)	Surgical education	Video-based virtual education offers a realistic alternative to face-to-face teaching or conventional textbooks in times of restricted access to the operating theatre.
:1	Development of surgical competence in veterinary students using a flipped classroom approach	Evaluate the effect of flipped classroom CSL training on students' self-efficacy and practical surgical skills	Quasi-experimental Study	veterinary	demonstrated the feasibility and value of implementing an FC approach in combination with CSL training Online learning paths were studied to prepare students for CSL training to optimize time and staff resources available in the CSL. This approach resulted in a significant improvement in self-efficacy and surgical skills
:1	A comparison of the flipped classroom model for medical student education in ophthalmology before and during the COVID-19 pandemic	Compare effectiveness of online vs. in-person flipped classroom in ophthalmology clerkship (interest, confidence, clinical skills)	Comparative study	Ophthalmology	Students in the online cohort were equally likely to feel comfortable evaluating eye complaints as those in the in-person cohort, more likely to report that the course enhanced their interest in ophthalmology, but less likely to

					feel comfortable using the direct ophthalmoscope.
21	Flipped ophthalmology classroom augmented with case-based learning	Assess perceptions of case-based flipped classroom vs. traditional lectures and effect on confidence in managing common ophthalmic complaints	Comparative study	Ophthalmology	Significant preference for the flipped classroom combined with case-based learning, accompanied by increased learner confidence and reduced anxiety, perceived pressure, and cognitive burden.
22	Flipped . classroom versus traditional didactic classroom in medical teaching: a comparative study	To compare effectiveness of flipped classroom vs traditional didactic lectures in medical teaching through knowledge retention and student feedback	Quasi-experimental Study	Medical education	Positive feedback of undergraduate surgical students from the implementation of the flipped classroom model
23	Effectiveness comparison between blended learning of histology practical in flipped physical classrooms and flipped virtual classrooms for MBBS students	To compare the effectiveness of blended learning in histology practical using flipped physical classrooms versus flipped virtual classrooms for MBBS students	Quasi-experimental Cohort Study	Histology practical	The effectiveness of the physical flipped classroom model and the increase in test scores and interactions compared to the virtual flipped classroom model Evaluation of physical and virtual flipped class model in increasing exam scores and student satisfaction compared to traditional physical class

2	Validation of use of flipped classroom for surgery core clerkships	To validate the use and effectiveness of the flipped classroom model in surgery core clerkships through comparison of academic outcomes and learner feedback	Quasi-experimental Study	Surgery core clerkships	Improving time management for instructors to use the flipped classroom model and the possibility of training and development in other components of the surgical curriculum
2	Design of a novel online, modular, flipped-classroom surgical curriculum for East, Central, and Southern Africa.	Describe a structured approach to developing a standardized curriculum for surgical trainees in East, Central, and Southern Africa (ECSA).	Quasi-experimental Study	Surgery	Present the systematic design of a large-scale, context-relevant, data-driven surgical curriculum for the ECSA region by utilizing Kern's 6-step approach.
2	Effectiveness of a combined problem-based learning and flipped classroom teaching method in ophthalmic clinical skill training.	Effectiveness of a combined problem-based learning and flipped classroom teaching method in ophthalmic clinical skill training.	Quasi-experimental mixed-methods	Ophthalmology & Clinical Skills Training	Combining flipped classroom with problem-based learning improved clinical ophthalmology skills (such as examination and management of complex cases) in medical students, increased confidence and satisfaction, and was more efficient than the traditional method.
3	Flipped . classroom applied to Neurosurgery in undergraduate medical education	To compare academic achievement in Neurosurgery using flipped classroom vs. traditional lectures in undergraduate	Quasi-experimental Study	Neurosurgery education	Reducing the dropout rate and increasing the score of neurosurgery students due to the use of the flipped classroom

		medical students			
23	Learner preferences and perceptions of virtual hand surgery education during the COVID-19 pandemic.	To assess learner preferences and perceptions of a virtual flipped classroom curriculum in hand surgery during the COVID-19 pandemic	Cross-sectional Study	Hand surgery education	The effectiveness of the virtual inverted class model in residency students of hand surgery, orthopedic surgery and plastic surgery
23	Application of a new multi-element integrated teaching mode based on bite-sized teaching, flipped classroom, and MOOC in clinical teaching of obstetrics and gynaecology	To assess the impact of a new multi-element teaching mode on learner perception, knowledge mastery, and satisfaction in obstetrics and gynaecology clinical teaching	Quasi-experimental Study	Clinical obstetrics and gynaecology education	The effectiveness of the inverted class teaching method and increasing mastery of gynecological and clinical knowledge of surgery and obstetrics students
24	Flipped classroom teaching model with video instruction improves skills in local anesthesia training.	To investigate if flipped classroom with procedural video instruction improves skills and confidence in local anesthesia administration compared to traditional methods	Cross-sectional Study	Dental local anesthesia skills	Improving procedural skills and increasing self-confidence, as well as increasing academic achievement in effect Implementation of the flipped class model based on the presentation of local anesthesia video content
24	Effectiveness of the Flipped Classroom Teaching and Learning Method Among	To evaluate the efficacy of the flipped classroom method and students'	Cross-sectional Study	physiology	Students' belief in the effectiveness of the flipped

	Underachievers in Physiology: Experience from a Tertiary Care Teaching Hospital.	perception among underachieving first-year medical students in physiology			classroom method and improving cognitive skills, analytical thinking, and increasing performance in final exams
24	Effectiveness of a flipped classroom for undergraduate students in implant dentistry hands-on course.	To compare the effectiveness of flipped classroom versus traditional method in an implant dentistry hands-on course for undergraduate students focusing on skill accuracy and learning outcomes	Quasi-experimental Study	Implant dentistry hands-on training	The effectiveness of the flipped classroom in improving the scientific skills of dental implant surgery compared to lectures
24	The application and influence of “Small Private Online Course” based on flipped classroom teaching model in the course of fundamental operations in surgery in China.	To evaluate the application and influence of SPOC-based flipped classroom teaching model on learning outcomes and teaching effectiveness in fundamental operations in surgery course.	Quasi-experimental Study	fundamental operations in surgery	found that SPOC + flipped classroom could significantly increase the efficacy of the class and enhance the ability of the students compared with the traditional method. The new teaching model could have a positive influence on medical students' basic knowledge and operational skills.
24	The application of flipped classroom teaching model combining scientific research	To apply and evaluate the flipped classroom teaching model combined with scientific	Mixed-methods Study	Thoracic surgery	The flipped classroom model encourages

	expansion in the teaching of thoracic surgery	research expansion in thoracic surgery teaching			active learning, where students prepare before class, leading to better retention of complex surgical concepts.
24	Flipped Classroom Based on Outcomes-Based Education Improves Student Engagement and Clinical Analysis Competence in Undergraduate Ophthalmology Clerkship	Assessing the impact of outcome-based flipped classroom on student engagement and clinical analysis competency in ophthalmology clerkship	Quasi-experimental Study	Ophthalmology	Flipped classroom increased engagement, improved clinical analysis competence, and higher student satisfaction.
24	Application of flipped classroom to teaching diabetic retinopathy and glaucoma in ophthalmology undergraduate education: a randomized study	Comparing flipped classroom with traditional method in teaching diabetic retinopathy and glaucoma (complex eye diseases with surgical aspects)	Randomized Controlled Trial (RCT)	Ophthalmology	Students in the flipped group showed better performance and greater preference; they gained a better understanding of the relevant procedures.
24	Education in . focus: Significant improvements in student learning and satisfaction with ophthalmology teaching delivered using a blended learning .approach	Assessing the impact of a blended (including flipped) approach on learning and satisfaction in ophthalmology education, covering topics such as diabetic retinopathy	Quasi-experimental Study	Ophthalmology Teaching	Significant improvement in learning and satisfaction; students better understood the concepts of retinopathy and glaucoma
25	Simulation-Based Flipped Classroom in Surgical Suturing Technique:	A survey of professors' and students' experiences of a simulation-based flipped	Qualitative Exploratory Study	Surgical Education (Basic Surgical Skills)	Students and faculty report high engagement, better learning of practical suture

	Faculty and Medical Students' Experiences at Soroti University.	classroom for surgical suture technique.			skills, and satisfaction.
25	Enhancing ophthalmology education through a mobile flipped classroom: a new teaching method.	Assessing the impact of mobile flipped classroom on OCT interpretation skills in glaucoma and student satisfaction.	Quasi-experimental Study	Ophthalmology	The mobile flipped classroom approach (mobile app– and video-based OCT training combined with discussion) led to a significant improvement in OCT interpretation skills and high learner satisfaction, supporting its effectiveness for glaucoma diagnosis and management education.
25	Application of the flipped classroom combined with BOPPPS model in standardized residency training for gastrointestinal surgery	Evaluation of the Flipped Classroom and BOPPPS Model in Gastrointestinal Surgery Residency Training	Quasi-experimental Study	Gastrointestinal Surgery	The combined use of the flipped classroom and the BOPPPS model was able to improve the trainees' rotation experience, increase their performance, and raise their final grades.
25	Enhancing Resident Engagement and Oral Board Preparation Through a Flipped Classroom Model for the American Board of Surgery	Improving resident engagement and preparation for surgical oral board	Quasi-experimental Study	General Surgery	The flipped classroom combined with oral scenario–based teaching appears to be an effective strategy for enhancing resident engagement and preparation for oral board examinations; however, its effectiveness has primarily been evaluated

					based on residents' self-reported feedback rather than objective board performance outcomes.
25	Advancements in orthopaedic medical Education: Exploring novel teaching strategies–A qualitative systematic review	This systematic review analyzed qualitative data from multiple studies on novel teaching strategies in orthopaedic education, including flipped classrooms, to assess advancements in conceptual understanding and skill acquisition among medical students and residents.	Qualitative Systematic Review	Orthopaedic	The flipped classroom model significantly enhanced conceptual understanding of complex orthopaedic procedures, such as joint replacements and fracture management, by shifting passive learning to pre-class activities and using in-class time for interactive discussions and simulations. This approach led to improved retention of surgical concepts, higher student engagement, and better performance in practical assessments compared to traditional lectures, though it required more preparation time from educators.
25	A flipped classroom improves medical students' skills in managing medical emergencies—an intervention-control study	A flipped classroom improves medical students' skills in managing medical emergencies an intervention-control study	Quasi-experimental Study	Emergency Medicine & Clinical Skills	Flipped classroom combined with simulation-based training more effectively increased medical emergency management skills (including surgical/clinical

					aspects) in medical students, improved practical readiness, and was superior to traditional control.
25	Comparison of flipped classroom and lecture-based models in a radiology residency training program	Comparison of flipped classroom and lecture-based models in a radiology residency training program	Quasi-experimental Study	Radiology	Flipped classroom in radiology residency training (related to surgery) improved academic performance and understanding of complex imaging concepts and was more effective than traditional lectures.
26	The Flipped Classroom Effect: Improving Faculty and Resident Engagement and Satisfaction in Ophthalmology Residency.	To evaluate the longitudinal impact and sustainability of a flipped classroom model (MOLE) on faculty and resident satisfaction, engagement, and educational outcomes in ophthalmology residency over 3 years.	Longitudinal Quasi-experimental Study (3-year comparative)	Ophthalmology	The flipped model initially increased resident/faculty engagement and satisfaction, but preference declined slightly over 3 years; initially beneficial for ophthalmic surgical education, but requires modifications for sustainability.

Narrative Synthesis Approach

For the synthesis of extracted data, we adopted the structured framework proposed by Popay et al. (2006), which is specifically designed for systematic reviews with heterogeneous evidence. This framework comprises four sequential stages: (1) developing a preliminary synthesis through thematic grouping of studies by surgical specialty, intervention components, and educational outcomes; (2) exploring relationships within and between studies to identify patterns, consistencies, and contradictions in effectiveness across different contexts; (3) assessing the robustness of the synthesis by systematically considering the methodological quality of included studies and their contextual relevance; and (4) concluding and formulating recommendations grounded in the synthesized evidence. This

methodological approach enabled us to integrate diverse quantitative and qualitative findings while maintaining a transparent, rigorous, and replicable analytical process (53).

Distribution of Studies by Surgical Field

The reviewed studies demonstrated a diverse yet concentrated distribution across various surgical and medical education domains. The majority of investigations focused on ophthalmology (n=8, 22.9%), reflecting a strong interest in applying the flipped classroom model to the teaching of complex visual and procedural ophthalmic concepts such as diabetic retinopathy, glaucoma, and clinical ophthalmology skills. This was followed by general surgery and broad surgical education (n=7, 20.0%), which encompassed undergraduate and residency training in core surgical principles, trauma, and fundamental operative skills.

Other fields included orthopaedics (n=2), neurosurgery (n=2), implant dentistry and dental local anesthesia (n=2), histology with surgical relevance (n=2), and a smaller number of studies in otolaryngology, hand/plastic surgery, obstetrics and gynaecology, gastrointestinal surgery, thoracic surgery, veterinary surgical education, emergency medicine, radiology, and physiology (each n=1). Additionally, three studies (n=3) adopted a broader multi-disciplinary surgical education approach without limiting to a single subspecialty. Several studies across these domains addressed procedural and technical skills training (e.g., suturing, local anesthesia, and implant placement) as well as cognitive and clinical reasoning aspects of complex surgical concepts.

This distribution highlights that while the flipped classroom model has been most extensively explored in ophthalmology and general surgery fields that benefit significantly from visual, case-based, and procedural learning, there remain considerable gaps in several high-stakes subspecialties. Notable absences or limited representation were observed in cardiothoracic surgery, urology, pediatric surgery, vascular surgery, transplant surgery, and oncologic surgery. These gaps suggest that future research should prioritize evaluating the effectiveness of the online flipped classroom model in these complex and procedurally demanding areas to achieve a more comprehensive understanding of its utility across the full spectrum of surgical education.

Synthesis of Findings

Based on the analyzed data, the included studies were categorized into four primary thematic areas:

- ***Learning Outcomes and Effectiveness:*** The majority of studies investigated the impact of the flipped classroom on academic achievement and knowledge retention in disciplines such as neurosurgery, histology, and ophthalmology. Findings highlighted significant improvements in exam scores, mastery of clinical knowledge, and procedural skills (e.g., surgical suturing and local anesthesia) compared to traditional methods.
- ***Student and Faculty Satisfaction, Perceptions, and Engagement:*** Multiple articles focused on evaluating students’ and faculty's attitudes, reporting high levels of satisfaction, increased

engagement, and a significant preference for the flipped model. This approach was associated with increased learner confidence and a reduction in anxiety and perceived pressure.

- ***Technological and Multimodal Integration:*** Studies explored the use of various digital tools, including mobile applications, Small Private Online Courses (SPOCs), MOOCs, and video-based instruction. These tools were used to facilitate virtual flipped classrooms and online learning paths, particularly ensuring continuity during the COVID-19 pandemic. These technologies facilitated flexible and learner-centered educational environments and supported the continuity of surgical education during and after the COVID-19 pandemic.
- ***Methodological and Curricular Comparisons:*** Research compared the effectiveness of physical versus virtual flipped classrooms and integrated models like FC combined with BOPPPS or Problem-Based Learning (PBL). While most studies reported positive educational outcomes, a small number found no statistically significant differences in academic performance when compared with traditional lecture-based approaches.

Overall, the findings indicate that while the flipped classroom is increasingly integrated into surgical education, there is a clear emphasis on its effectiveness in enhancing practical skills and student engagement. However, results also highlight the increased preparation time required for educators and the need for sustainability in longitudinal implementation.

Field of Focus: Among the articles, the focus areas were reported in learning outcomes and effectiveness (29 articles), student satisfaction and engagement (21 articles), technological integration (11 articles), and methodological comparisons (24 articles).

Type of Articles: Of the 35 identified articles, 23 were quasi-experimental studies, 3 were comparative studies, 4 were surveys/cross-sectional studies, 2 were randomized controlled trials, 2 were mixed-methods studies, and 1 was a qualitative study

Collectively, these findings highlight the growing role of the flipped classroom in modernizing surgical training, improving both conceptual understanding and clinical analysis competence across various surgical specialties.

Key findings

The reviewed literature revealed several recurring educational themes related to the implementation of the online flipped classroom model in surgical and medical education, including: improvement of learning outcomes and academic performance, enhancement of knowledge retention and conceptual understanding, increased student engagement and satisfaction, development of clinical reasoning and procedural skills, integration of digital and technology-enhanced learning tools, flexibility in curriculum delivery, comparison with traditional lecture-based approaches, and promotion of active and self-directed learning. Furthermore, several studies highlighted the value of multimodal educational strategies, such as simulation-based learning, mobile applications, video-assisted instruction, SPOCs,

and blended learning environments, in strengthening the effectiveness of flipped classroom interventions. Table 4 provides a detailed summary of the extracted key findings.

Table 4. Key Findings and Educational Themes of Online Flipped Classroom in Surgical Education

Theme	Related Articles	Brief Description
Learning Outcomes and Educational Effectiveness	Durai & Mohanraj (2019), Kolahdouzan et al. (2020), Aristotle et al. (2021), Akbarialiabad et al. (2021), Bhavsar et al. (2022), González et al. (2023), Wu et al. (2024), Zhou et al. (2024), Liu et al. (2024), Doyle et al. (2024), Luo et al. (2025), Hou et al. (2025)	Improved academic achievement, knowledge acquisition, knowledge retention, examination performance, and conceptual understanding of complex surgical topics.
Student and Faculty Satisfaction, Perceptions, and Engagement	Kohler et al. (2020), Chick et al. (2021), Akbarialiabad et al. (2021), Yom et al. (2021), Bhavsar et al. (2022), Bartoletta et al. (2023), Shireesha et al. (2024), Liu et al. (2024), Musa et al. (2025), Duncan et al. (2025), Thareja et al. (2026)	Reported high levels of learner and faculty satisfaction, positive perceptions toward flipped learning, increased engagement, motivation, confidence, and active participation in educational activities.
Clinical Reasoning and Procedural Skill Development	Durai & Mohanraj (2019), Decloedt et al. (2021), Chen et al. (2024), Wu et al. (2024), Zhou et al. (2024), Zhu et al. (2024), Wang et al. (2024), Ruesseler et al. (2025)	Enhanced clinical reasoning, analytical thinking, surgical competence, procedural skills, practical performance, and self-efficacy.
Technological and Multimodal Learning Integration	Schmitz (2021), Parker et al. (2022), Liao et al. (2023), Zhou et al. (2024), Wang et al. (2025), Doyle et al. (2024)	Integration of digital learning tools including online platforms, simulation-based education, mobile learning, SPOCs, MOOCs, and video-assisted instruction.
Comparison with Traditional Teaching Approaches	Sajid et al. (2020), Yom et al. (2021), Bhavsar et al. (2022), Zhong et al. (2022), Wu et al. (2024), Liu et al. (2024), Hou et al. (2025)	Comparative evaluations generally favored flipped classroom models over conventional lecture-based teaching, although some studies reported comparable outcomes.
Curriculum Innovation and Flexible Learning Environments	Barrett et al. (2022), Parker et al. (2022), Zhou et al. (2024), Duncan et al. (2025), Roy et al. (2025)	Flipped classroom approaches supported curriculum modernization, learner-centered education, flexibility, and continuity of surgical training across diverse educational settings.
Active and Self-Directed Learning	Chick et al. (2021), Akbarialiabad et al. (2021), González et al. (2023), Zhou et al. (2024), Roy et al. (2025)	Encouraged student autonomy, preparation before class, active participation during sessions, and development of lifelong learning skills.

Discussion

This Narrative Synthesis of the impact of the online flipped classroom (FC) model on medical students' understanding of complex surgical concepts identified 35 studies that met the inclusion and exclusion criteria. Overall, the majority of studies demonstrated that the FC model is associated with enhanced learning outcomes across diverse surgical and medical disciplines. For instance, González et al. (2023) reported a reduction in dropout rates alongside improved academic performance among neurosurgery students exposed to the flipped classroom approach (34). Similarly, Chen et al. (2024) found significant improvements in procedural competence and self-confidence among students trained in local anesthesia through video-based flipped classroom interventions (37). These findings are consistent with the foundational pedagogical principle of FC, which emphasizes pre-class preparation and the use of in-class time for active learning, problem-solving, and clinical application.

A further recurring theme across the included studies is the positive influence of FC on student engagement, motivation, and satisfaction. Bhavsar et al. (2022) reported favorable feedback from undergraduate surgical students who experienced flipped classroom instruction compared with traditional didactic teaching (30). In parallel, Chick et al. (2021) highlighted that surgical trainees preferred the FC model for examination preparation due to its interactive and learner-centered structure, which fosters deeper engagement with educational content (24). Collectively, these findings reinforce the notion that FC promotes active learning environments that enhance collaboration, autonomy, and learner confidence, all of which are essential components of effective medical education.

Despite these generally positive findings, the evidence also reveals important inconsistencies. Sajid et al. (2020) found no statistically significant difference between FC and traditional lecture-based teaching in general surgery education, suggesting that the effectiveness of FC may be context-dependent (22). This variability is further supported by large-scale evidence indicating that FC outcomes are strongly influenced by implementation quality, instructional design, and learner compliance rather than the pedagogical model itself (54). Similarly, causal machine learning analyses have demonstrated that improvements in academic performance may diminish or disappear when pre-class engagement is low or when instructional alignment is weak (55). These findings suggest that FC should be conceptualized as a pedagogical framework rather than an inherently superior instructional method.

The integration of educational technology represents a core component of the flipped classroom model. Digital tools such as video lectures, Small Private Online Courses (SPOCs), MOOCs, and mobile learning applications enable flexible, self-paced pre-class learning, thereby enhancing conceptual preparation before interactive in-class sessions. For example, Zhou et al. (2024) demonstrated that SPOC-based flipped classroom interventions significantly improved both foundational knowledge and surgical operational skills (40). In addition, Sun et al. (2025) confirmed that FC approaches in clinical medicine are associated with improved theoretical understanding and procedural competence among medical students (56). However, the reliance on digital infrastructure raises concerns regarding accessibility and equity, as disparities in technological resources may influence learning opportunities across student populations.

Moreover, emerging evidence highlights the growing effectiveness of multimodal and simulation-enhanced FC approaches. Agostino et al. (2024) reported that combining simulation-based learning with FC significantly improves perceived clinical skills compared to traditional training methods (57). Similarly, Wang et al. (2025) demonstrated that FC integrated with anesthesia crisis simulation enhanced performance in high-stakes clinical scenarios (58). Lin et al. (2025) further showed that multidisciplinary team-based FC models improved clinical teaching effectiveness in undergraduate medical education (59), while Hu et al. (2024) found that combining case-based learning with FC significantly enhanced bedside teaching performance in nephrology. These findings collectively suggest that hybrid instructional designs may amplify the educational benefits of FC in clinical and surgical training contexts (60).

The implementation of FC also requires substantial instructional planning and faculty readiness. Barrett et al. (2022) emphasized that FC adoption can improve instructor time management and facilitate the development of broader curricular components. However, the preparation of high-quality pre-class materials remains time-consuming and may limit widespread adoption. This challenge is particularly relevant in resource-constrained settings, where faculty workload and institutional support may influence implementation fidelity (32).

Recent meta-analytic evidence further supports the effectiveness of FC in medical education, particularly in improving learner satisfaction and knowledge acquisition, although effects on objective academic performance remain variable (61). Similarly, Shi et al. (2025) demonstrated that FC combined with case-based learning yields superior outcomes in clinical reasoning compared to traditional lecture-based approaches (62). Nevertheless, earlier meta-analyses indicate that improvements in academic performance are often moderate and highly context-dependent (Hew & Lo, 2018). Collectively, these findings suggest that FC effectiveness is not uniform and is strongly influenced by instructional design quality, learner engagement, and contextual implementation factors (63).

In this regard, systematic reviews emphasize that FC success depends more on pedagogical execution than on the model itself (64). Similarly, Zhang et al. (2024) and Czarnowske et al. (2025) highlight that variability in outcomes is primarily driven by pre-class accountability, instructional alignment, and teaching quality. Therefore, FC should be regarded as a structured instructional framework requiring careful design rather than a universally superior teaching method (54–55).

Emerging synthesis of evidence also indicates that FC, when combined with complementary instructional strategies such as simulation-based training, multidisciplinary teaching, and case-based learning, yields more robust educational outcomes. For example, Hu et al. (2024) and Lin et al. (2025) demonstrated enhanced clinical performance when FC was integrated with structured collaborative approaches (59–60). Similarly, Wang et al. (2025) showed improved crisis management skills in anesthesia training through FC-based simulation models (58). These findings reinforce the potential of FC as part of a broader multimodal educational ecosystem rather than as a standalone intervention.

Overall, the findings of this review highlight that the flipped classroom model plays a significant role in modernizing surgical education by enhancing conceptual understanding, procedural skills, and learner engagement. However, its effectiveness is heterogeneous and strongly dependent on instructional design quality, technological integration, and learner compliance. While FC offers substantial advantages in promoting active and self-directed learning, its successful implementation requires careful curricular planning, faculty training, and sustained institutional support to ensure long-term effectiveness and scalability in surgical education contexts.

Conclusion

This systematic review with narrative synthesis demonstrates that the online flipped classroom model has a generally positive impact on undergraduate medical students' understanding and comprehension of complex surgical concepts. Compared to traditional lecture-based methods, the majority of included studies reported significant improvements in knowledge acquisition, retention, exam performance, and procedural skills (such as surgical suturing, local anesthesia administration, and implant placement) across domains including ophthalmology, neurosurgery, general surgery, and histology. The model also consistently enhanced student engagement, satisfaction, confidence, and clinical reasoning while reducing anxiety.

These benefits were particularly evident when the flipped classroom was integrated with technology-enhanced tools (e.g., videos, SPOCs, MOOCs, mobile applications) and multimodal strategies such as simulation or case-based learning. However, the effectiveness of the model is not automatic; a small number of studies found no statistically significant differences in academic performance, highlighting its sensitivity to instructional design quality, implementation fidelity, educator preparation time, and curricular alignment. The evidence base is dominated by quasi-experimental designs with only a few randomized controlled trials, and notable gaps remain in several high-stakes surgical subspecialties (e.g., cardiothoracic, urology, vascular, and oncologic surgery).

Overall, the online flipped classroom should be regarded as a promising, learner-centered, and implementation-sensitive educational strategy rather than a universally superior method. Its successful integration into surgical curricula requires thoughtful design, adequate resources, and alignment with specific learning objectives. Future research should prioritize well-designed randomized controlled trials, standardized outcome measures (including long-term retention and procedural competence), longitudinal studies, and evaluation in underrepresented surgical domains to provide higher-quality evidence for its broader adoption in undergraduate medical education.

Recommendations for Implementation

Effective implementation of the flipped classroom in surgical education requires structured faculty development, with a particular focus on instructional design, facilitation of active learning, and alignment between pre-class and in-class activities. Training clinical educators in these competencies is essential to ensure consistent and high-quality implementation.

At the curricular level, the flipped classroom should be embedded within well-structured educational programs rather than applied as an isolated teaching strategy. Institutional support, including appropriate workload allocation, learning management systems, and digital infrastructure, is critical to facilitate sustainable implementation. This approach is particularly well-suited for complex, procedural, and clinically oriented subjects, where pre-class preparation can enhance in-class application, clinical reasoning, and skill acquisition. In contrast, its use should be carefully designed rather than assumed to be equally effective for all types of content.

In addition, learner accountability mechanisms such as structured pre-class assignments and formative assessments are essential to ensure active engagement with preparatory materials. Finally, integrating the flipped classroom with complementary approaches such as simulation-based training, case-based learning, and other technology-enhanced educational strategies is likely to further enhance its educational impact and support deeper learning outcomes in medical and surgical education.

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Availability of data and materials

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Author's contributions

B.Gh.H and **N.Z** played the leading roles in the conceptualization, design, coordination, and overall conduct of this critical narrative review, as well as in the interpretation of the findings. **B.Gh.H** conducted the literature review, performed data extraction and synthesis, and prepared the initial draft of the manuscript. **N.Z** supervised the study process and critically reviewed and revised the manuscript for important intellectual content. **E.N** contributed to the methodological development of the review, interpretation of findings, and revision of the manuscript. **B.Gh.H** participated in article screening, evaluation of the included studies, and editorial revision of the manuscript. **S.N** contributed to the evaluation of studies, interpretation of results, and final editing of the manuscript. All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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Figures

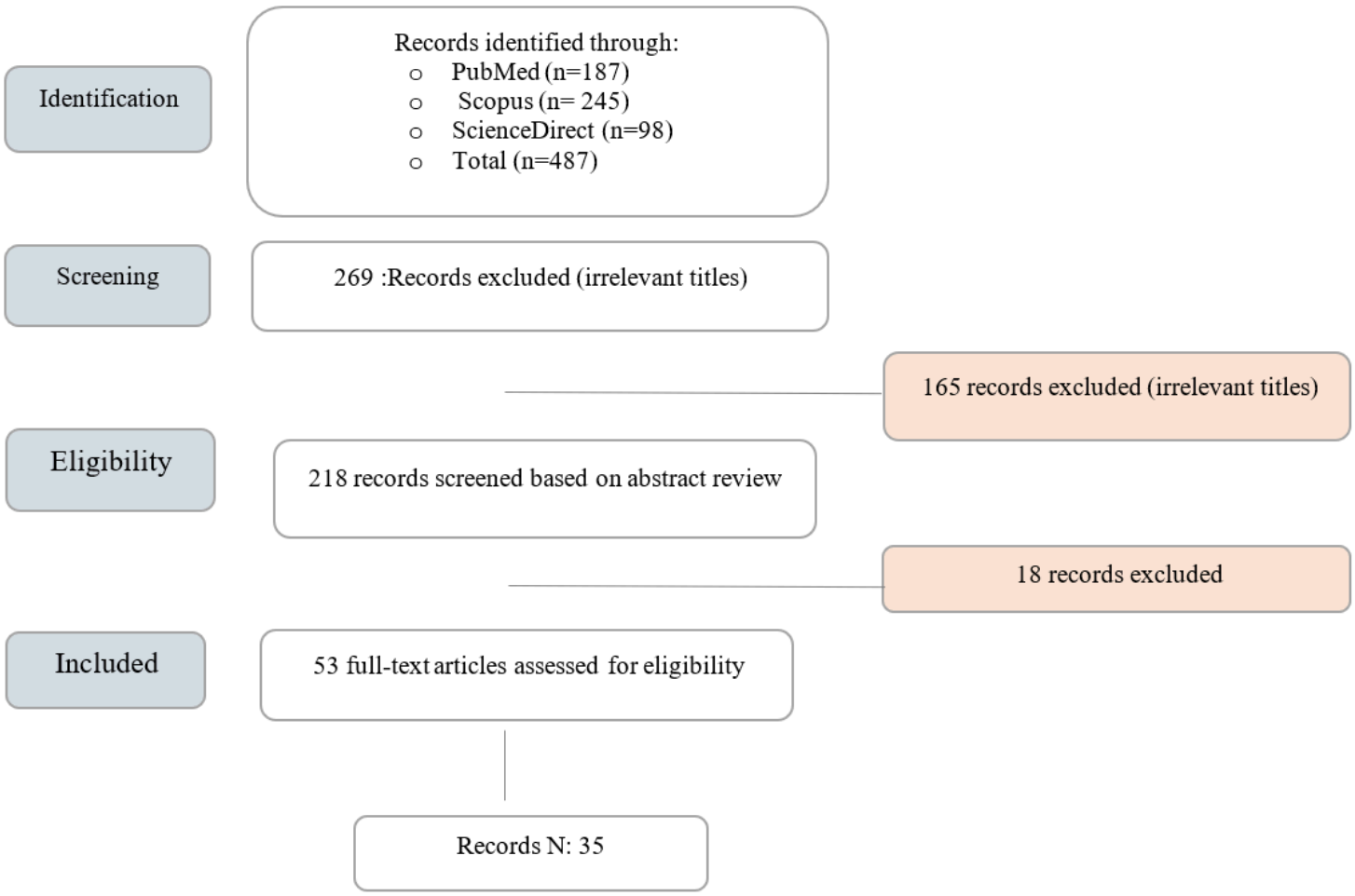


Figure 1

PRISMA flow-diagram for systematic reviews