Health Professions Education

Volume 10 | Issue 1 Article 8

February 2024

Optimizing the Design of the Flipped Classroom to Teach Technical Clinical Skills to Medical Students

Mohamed Buhary Farah Yoosoof
Department of Paediatrics, General Sir John Kotalawela Defence University, Rathmalana, Sri Lanka, farahyoosoof@kdu.ac

Fathima Rizka Ihsan
Postgraduate Institute of Medicine, University of Colombo, Sri Lanka

Recommended Citation

Yoosoof, Mohamed Buhary Farah and Ihsan, Fathima Rizka (2024) "Optimizing the Design of the Flipped Classroom to Teach Technical Clinical Skills to Medical Students," *Health Professions Education*: Vol. 10: Iss. 1, Article 8.
DOI: 10.55890/2452-3011.1058
Available at: https://hpe.researchcommons.org/journal/vol10/iss1/8

GOOD PRACTICES

Optimizing the Design of the Flipped Classroom to Teach Technical Clinical Skills to Medical Students

Farah Yoosoof [a,*], Fathima R. Ihsan [b]

[a] Department of Paediatrics, General Sir John Kotalawala Defence University, Rathmalana, Sri Lanka
[b] Postgraduate Institute of Medicine, University of Colombo, Sri Lanka

Abstract

Objectives: **To explore the published practices in the use of the flipped classroom for training in technical clinical skills at the 3 stages of design; pre-class, in-class and after-class, seeking links between aspects of design and soft and hard outcomes.**

Methods: **A review of the literature on the use of the flipped classroom to teach technical clinical skills to medical and nursing students over a 15 year period (2007−2021) was conducted. Data on the 3 stages of design, as well as outcomes, were extracted and analysed independently by both reviewers. Reviewers then independently sought any links between the two, finalizing the synthesis of data by discussion and reaching a consensus.**

Results: **Positive student views were attributed to the flexibility and adaptability of the flipped classroom, allowing the integration of multiple teaching approaches to suit diverse learning styles. A plethora of preparatory material, predominantly online, have resulted in mixed outcomes. However, the data indicated that customized material as well as combinations of different modalities of preparatory material which complemented simulated and collaborative in-class activities were more efficient. Embedded pre-session self-assessments ensure accountability and help gauge student preparation for tailored instruction. Despite being learner-centred, the instructor seems to remain invaluable as a guide and facilitator. While student satisfaction was predominantly positive, increased student motivation and confidence did not always accompany significantly improved knowledge and/or skills gain.**

Discussion: **Any gain in skills may be attributed to the ability of the flipped classroom to support the complex interaction between psychomotor, cognitive and affective factors on skill performance. The evidence was synthesized to provide pragmatic insight in the form of 8 tips for the evidence-based design of the flipped classroom for teaching technical clinical skills to ensure maximum learning efficiency in undergraduate medical education.**

Keywords: Flipped classroom, Intervention design, Procedural skills, Technical clinical skills, Undergraduate medical education

1. Introduction

Competency in clinical skills (CS) is fundamental to medical practice and contributes to the professional identity of a doctor [1]. The term CS is used to describe a variety of activities performed by doctors in the clinical setting including physical examination, diagnosis, treatment, practical procedures and communication. CS are arbitrarily divided into non-technical and technical CS (TCS). In this review we focus on TCS, defined as CS involving a direct practical element [2] such as medical or surgical procedures.

In medical education (ME), the traditional approach to TCS training is predominantly behavioural. Frameworks such as the Deliberate Practice model proposed by Ericsson [3] involves repeated mechanical practice till the achievement of expertise. Besides this, professional competence in TCS also requires a solid foundation in conceptual, procedural and conditional knowledge related to the procedure [4]. However, when both knowledge

Received 17 February 2023; accepted 30 September 2023.
Available online 17 February 2024

* Corresponding author at: Department of Paediatrics, General Sir John Kotalawala Defence University, Kandawala Road, Rathmalana 10390, Sri Lanka.
E-mail address: farahyoosoof@kdu.ac (F. Yoosoof).

https://doi.org/10.55890/2452-3011.1058

sharing and hands-on practice occur simultaneously, the student is at risk of cognitive overload and learning inhibition [5]. Further, in-class knowledge sharing reduces the time available for hands-on practice. The Flipped Classroom (FC), comprising of the pre-class, in-class and after-class phases offers a promising teaching strategy to overcome these dilemmas.

By reversing the order of teaching events, the FC ensures that valuable and limited in-class time is spent in active application of knowledge and hands-on skills training within a collaborative environment. Knowledge sharing occurs during the pre-class component by independent, self-paced review of relevant material in preparation for in-class activities. Consolidation and retention of acquired knowledge and skills are facilitated through in-class application supported by real time feedback [6], as do assignment of follow-up, after class tasks [7]. By promoting self-regulatory learning behaviours, the FC garners learner interest and motivation [8,9] and promotes the habit of lifelong learning [10,11]. Thus, as a 'building block of curricular reform in modern competency-based ME' [12], the FC offers a flexible, student-centred pedagogical approach for TCS training.

Reviews of FC approach have shown that the FC is favoured by students [10,11,13–15]. Systematic reviews have demonstrated superior knowledge acquisition compared to other methods [13,16], but equivocal or inconclusive results in terms of skills acquisition and retention [11,13,17,18]. Such conflicting results may be explained by the versatility of the FC which allows a wide variation in design and application, leading to considerable heterogeneity in systematic reviews of the FC [10,15,16]. Given the broad outreach of CS, a wide variety of skills may be taught using any one of the many teaching methods including simulation, problem or task based learning. Beside this, diverse student learning styles and variations in technological and self-regulated learning ability may influence student motivation and outcomes [16]. It has also been suggested that the effects of the FC may differ between undergraduate and postgraduate students [17]. Additionally, the failure to control for learning techniques and learning time in reviews comparing the FC with traditional approaches have drawn criticism [19]. However, reviews that are more limited in scope have had more positive results [10,15,20,21].

Given the conflict resulting from outcome based studies, we opinioned that an in-depth and critical analysis of the *process* of how the FC has been used in existent studies may provide valuable insights on how best to manipulate the FC design to boost outcomes [7,8]. Based on these facts, we conducted a review of the existing flipped literature within a limited scope, aiming to explore the published practices of the FC in TCS training in undergraduate medical and nursing education, and link the reported outcomes to aspects of the FC design.

2. Methods

2.1. Overview

We summarized and synthesised the evidence from existent literature on how the FC has been used to teach TCS to medical students (MS) and nursing students over a period of 15 years. Being essentially a practical profession [22], studies conducted in the field of nursing were included with the hope of deriving significant information. The search was filtered for articles from 2007 (the year in which the concept of the FC emerged), to the month in which the search was done (September 2021). The methodological rigor and the quality of the studies were not analysed because it was not intended to study the efficiency of the FC in teaching TCS over other methods, given the difficulty in controlling for heterogeneity. Following data analysis, we synthesized the findings and presented it in the form of a narrative overview, providing a broad outline of the possibilities for the implementation of the FC in TCS training [23], as well as pragmatic insight for those seeking to do so. Since this study did not involve the collection of primary data, the authors deemed that ethical approval was not required.

2.2. Search strategy

In order to identify relevant papers, both researchers performed database searches independently in PubMed, MEDLINE, ERIC, MedEdPublish and Google Scholar. The search strategy was formulated using a combination of Mesh terms 'Education, Medical, Undergraduate', 'Education, Medical', 'Students, Nursing', 'Competency-Based Education', 'Clinical Competence', 'Professional Competence', 'Motor Skills' and the keywords 'procedural skills', 'skills lab', 'practical skills', 'psychomotor skills', 'skills acquisition', 'flipped classroom', 'inverted classroom', 'blended learning', limiting to articles in the English language. Additionally, the bibliographies of the retrieved papers were manually searched for further relevant articles.

2.3. Article screening and selection

We independently conducted title screening of database search hits followed by abstract screening.

Working separately, we removed duplicates and independently reviewed the lists of selected abstracts, including 19 from the bibliography search, to determine the final list. We deemed studies relevant if they involved the use of any form of asynchronous, independent learning followed by face-to-face training. We also retained abstracts that used the term "blended". We then screened the selected abstracts by applying post-hoc inclusion and exclusion criteria as summarised in the search strategy presented in Fig. 1. Where there was a conflict of opinion, a discussion between the authors took place to resolve the conflict and reach a consensus. Of the 68 abstracts that we selected, we included 25 papers in the review.

2.4. Data extraction

The authors independently extracted and analysed data regarding the scope of use, details of implementation and reported outcomes of the FC based on the published information. The authors then compared the collected data through discussion and finalized the analysis of findings.

3. Discussion

3.1. Scope of use

The titles and geographical origin of the included studies are tabulated in the Appendix. Over the last 15 years, the FC has been used in preclerkship and clerkship TCS training equally frequently (ten studies each), with one study [24] recruiting students across different levels of study (Table 1). The use of the flipped approach to teach TCS to clinically inexperienced preclerkship MS may be beneficial, because pre-class preparation creates an opportunity to present essential theoretical background, which in turn may help to reduce unfamiliarity and mitigate the challenges of preclerkship CS training [25].

Application of the FC in ME has not been limited to teaching singular skills or sets of related skills. In fact, learning units such as modules, entire curricula, and even clerkships have been flipped (Table 1) with variable results (Tables 2 and 3). Successful applications include the flipping of multi-disciplinary procedural skill curricula with simulation-based learning as well as discipline-specific procedural skill modules in Paediatrics [26], Radiology [27] and nursing [28,29]. However, when entire clerkships were conducted with the flipped approach as those described in Emergency Medicine [30], Surgery [31] and Geriatrics [32], outcomes were mixed. This suggests that flipping content that is vast or complex as in a clerkship, places a great deal of responsibility on the student and may prove overwhelming and demotivating. Thus, the applicability of FC appears to depend on the amenability of the learning content to the FC framework and feasibility of achieving the learning objectives within the scope of the FC. Where learning content is extensive or difficult, combining traditional teacher-centred, guided instruction and the FC in a hybrid approach may be more successful [33].

3.2. Pre-class phase

Familiarization with the concept of the FC prior to implementation can influence student engagement with the preparatory material [28,34,35]. For example, Sezer and Elcin, who included a pre-intervention orientation to the FC, showed that all but 7 % of the students self-reported reviewing the pre-class material in full [35]. Alternatively, in a study that did not do so, 27.5% students self-reported not going through all the material and more than half the students reported feeling unfamiliar and apprehensive [36]. Providing clear instructions and a study-plan can ensure engagement by helping students organize self-study [26,36]. Further, orientation of all stakeholders with the concept of the FC and their changing roles ensures buy-in and positive outcomes [14,16].

Almost all the studies (n = 23) used an online platform to deliver a plethora of preparatory material except for two, in which the modality was unclear [37,38]. Students' views on online preparation was similar across studies, finding it interesting, informative, flexible in terms of being repeatedly accessible for self-paced study and helpful for in-class activities [29,31,32,34,36,39,40]. This is not surprising since MS are known to value the autonomy afforded by digital resources and are therefore more likely to engage with such material [41]. Technology also offers the leeway to incorporate context and authenticity in TCS training [42] which is known to promote lifelong learning and transferability to the work place [43]. For example, nursing students reported that a customized game-based learning platform to teach decision making in intravenous cannulation, provided an authentic context, promoted critical thinking and reduced anxiety in the clinical setting [40]. Thus, when designing preparatory material, teachers need to consider the nature of the material in line with the preferences of millennial learners [41]. However, the deciding factor in using technology should be its utility in ensuring learning, rather than its' novelty [12,44].

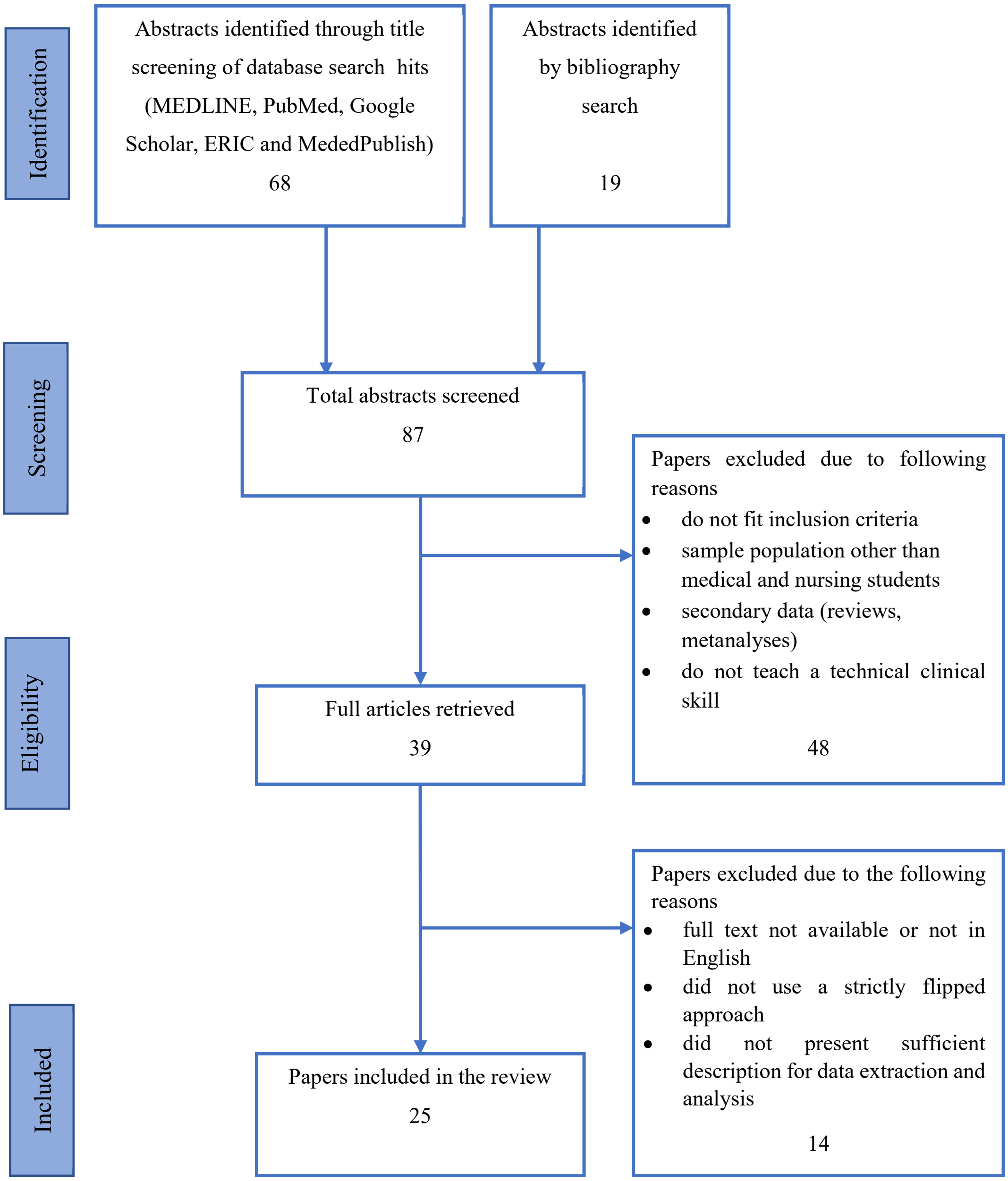

Fig. 1. Search strategy.

Analysis of pre-class material showed that close attention must also be paid to the content and volume of preparatory material to ensure student engagement and completion of pre-class activities. Fourteen of the studies opted for a single type of pre-session material, while 11 studies used a combination (Tables 2 and 3 respectively). The latter approach appears to be favored and considered beneficial by students based on views that variety catered to different learning styles [24,29,31,45]. A study of a course teaching a complex skill (laparoscopic suturing) using a single demonstration video for preparation with repeated demonstration in class, reported no difference in satisfaction between the flipped group and control group [36]. Another study teaching cardiopulmonary resuscitation using a single demonstration video was unsuccessful at showing significant improvement in skill performance [46]. Thus, demonstration videos alone may not be adequate to deliver the cognitive, psychomotor and affective aspects of complex skills [47]. On the contrary, a flipped Radiology clerkship using a custom-created online preparatory e-module including podcasts, tutorials and an interactive gaming and simulation platform was reviewed positively and resulted in superior knowledge gains

Table 1. Context and scope of flipped technical clinical skills training in undergraduate medicine and nursing.

	Taught skill or discipline	Preclerkship	Clerkship	Nursing
Specific skills	Adult resuscitation	Beom et al. [52] Nakanishi et al. [46]	Boysen-Osborn et al. [45]	
	Paediatric resuscitation	Thomson et al. [24]	Thomson et al. [24]	
	Suturing		Chiu et al. (laparoscopic) [56] Wu et al. [47]	
	Patient assessment			Choi et al. [36]
	Cannulation			Hwang & Chang [31] Sezer & Elcin [23]
	POCUS[a]	Khoury et al. [38]		
	Mass Casualty triage		Zheng et al. [51]	
Procedural skills lab	(teaching of a number of different procedural skills)	Ayandeh et al. [57] Battaglia et al. [37] Katz et al. [54] Reed et al. [53] Röhle et al. [58]	Gong et al. [39]	
Flipped curricula	Nursing			Kim & Jang [22] Rodrigues [34]
	Radiology	Evans & Thiessen [27]		
	Clinical Paediatrics	Uther et al. [26]		
Flipped clerkships	Radiology		Belfi et al. [34]	
	Emergency medicine		Heitz et al. [30]	
	Surgery		Liebert et al. [31]	
	Geriatrics		G.Lucchetti et al. [32]	

[a] Point of Care Ultrasound Scan.

when compared to traditional and independent learning groups [34]. This demonstrates that the choice and mix of pre-session material should be tailored to the complexity of the skill to be learnt.

Preparatory material should be simple enough to motivate self-study and challenging enough to promote self-regulation [48]. Videos, which are preferred by MS for CS training [49] were the most common pre-session material used. In a flipped surgery clerkship, Liebert et al. demonstrated that students preferred Khan style videos with digital inking of less than 10 min duration over PowerPoint or PowerPoint videos with digital inking [31]. This is in line with the cognitive principles of the

Table 2. Summary of studies using a single type of preparatory material.

Preparatory material		Author and year of publication	Self-Assessment or rat	In-class activities	Outcomes		
					Student Satisfaction	Knowledge Acquisition	Skills Acquisition
Videos	Custom demonstration videos	Chiu et al. [56]	-spaced learning	SBL multimodal practice, TW	positive	NM	+
		Katz et al. [54][a]			NM positive	NM	NM
		Evans & Thiessen [27]	–	practiced on each other		+	NM
	Generic demonstration videos	Nakanishi et al. [46]*	–	SBL	NM	NM	ND (at 6 months)
		Wu et al. [47]**[,a]	–	SBL	NM	NM	NM
	Video lecture	Liebert et al. [31]	pre-test	SBL, GBL, TW	positive	NM	NM
		Zheng et al. [51]	pre-test	CBL, SBL, TW	positive	+	ND (at 2 weeks)
		Hwang & Chang [40]	pre-test	SBL, GBL, TW	NM	+	NM
	PowerPoint with recorded explanation	Beom et al. [52]	-quiz	SBL, TW	positive	NM	ND
		Choi et al. [36][a]		SBL, TW	NM	NM	NM
Reading material	Peer written manual	Khoury et al. [38]	pre-test	SBL, TW	positive	+	+ (at 3 weeks)
	Skill-specific handbook	Battaglia et al. [37][a]	quiz	SBL	NM	NM	NM

+ Statistically significant difference or improved post-test performance; ND: no significant difference with control group; NM: not measured; CBL: Case-based Learning; GBL: Game-based learning; RAT: Readiness assurance test; SBL: Simulation-based learning; TW: Team work.
Videos freely available on these websites: Japanese Red Cross* New England Journal of Medicine**.
[a] Measured other outcomes discussed in text.

Table 3. Summary of studies using multiple types of preparatory material.

Author(s) and year of publication	Pre-session preparatory material	Self – assessment or RAT	In-class activities	Student satisfaction	Knowledge acquisition	Skills acquisition
Thomson et al. [24]	validated custom e-learning module[a]	pretest	SBL, TW	positive	+ (immediate & at 8 months)	+
Belfi et al. [34]	custom-made video podcasts, tutorials, games & interactive simulation	tutorials	CBL, GBL, TW	NM	+	NM
Heitz et al. [30]	web based reading, lecture material[a]	self-evaluation questions	independent clinical work, WBL	positive	ND	NM
Boysen-Osborn et al. [45]	recorded podcasts, TBL session	quiz, RAT	SBL, TW	marginally positive	+	NM
G.Lucchetti et al. [32]	video lecture (15–20 min), recommended reading	quiz	CBL, TBL, GBL, WBL	positive	+	ND
Reed et al. [53]	video podcasts, online journal	RAT	SBL	NM	NM	+ (immediate & at 1–9 months)
Rodrigues [29]	PP video, online journal article, clinical workbook	quiz	SBL	positive	NM	NM
Kim & Jang [28]	2 videos per module (10–15 min each) on theory and skills, educational material[a]	pretest	SBL, TBL	positive	+	+
Uther et al. [26]	videos[a], interactive tutorials	pretest	SBL, TW	positive	+ (immediate & at 9–17 months)	NM
Sezer & Elcin [35]	demonstration video, 4 recorded video lectures, additional reading, online logs	assignment	SBL, TW	positive	NM	+
Ayandeh et al. [57]	video (procedural & theory), required readings	–	SBL	NM	+ (at 2 & 7 months)	+
Röhle et al. [58]	videos[a], standard of conduct, handouts, student-teacher communication platform	online assessments	SBL	positive	NM	NM
Gong et al. [39]	demonstration videos, microlectures, screen- based simulation	online assessments	SBL, TW	positive	+	+

+ Statistically significant difference with control group or improved posttest performance; ND: no significant difference with control group; NM: not measured; CBL:Case based learning; GB: Game based learning; PP: PowerPoint; RAT: Readiness Assurance Test; SBL: Simulation-based learning; TBL: Team based learning; TW: Team Work; WBL: Work place based learning.
[a] Details not specified.

multimedia learning [50], which suggests that the combination of graphics and voice over used in Khan-style videos promotes efficient learning.

Student reports of stressful and time-consuming preparation could be attributed to the study load and complexity of material [36,45,51]. Comparing 9 h of podcasts and 10.5 h of Team-based learning (TBL) sessions for a flipped group with a historical cohort that received 12 h of didactic lectures, Boysen-Osborn et al. reported that only two third of the students listened to the podcasts, completing only up to three fourth of the total duration [45]. Students also found the TBL session redundant and time-consuming. Despite marked financial investment and preparation, the flipped group showed marginally superior knowledge acquisition than the historical cohort. In another study, students found custom-made videos of 90 min total viewing time a burden on their busy schedules [51]. Thus, lengthy, repetitive or redundant material may overwhelm students and demotivate them. However, simply offering the same material in different modalities appears to have no additional benefit besides releasing class time for active learning opportunities. For instance, Beom et al. were unable to detect any significant difference in satisfaction or performance between a control group who attended a didactic lecture and a flipped group who received the PowerPoint of the same lecture with a recorded explanation [52].

In several studies, students valued the complementary nature of preparatory material with the activities of the practical session [24,26,29,34,35]. While short custom-made videos and reading material were well received (Tables 2 and 3), a study that used a freely-available generic video which halved the faculty workload and instruction time, showed no significant difference in skills retention [46]. It appears that material that is customised and complements intended in-class activities engages students and promotes completion. Extraneous content in generic material may limit learning gains and despite its' ease of use, may not always be best.

Opportunities for self-assessment through quizzes or Readiness Assessment Tests (RATs) were either embedded in the preparation or given at the beginning of the class in all but 6 of the studies (Tables 2 and 3). Students were held accountable for self-preparation by permitting only those who pass the RAT to take part in practical training [53]. Self-assessments enable students to identify learning gaps and guide self-directed learning and were viewed positively by students [29,31,36]. For example, a study which provided serial engagement and repeated assessment with material through Spaced Learning led to higher confidence levels in the flipped group over the control group [54]. Quiz results also allow instructors to gauge the level of student preparedness, allowing tailored support during the class.

Peer communication and remote interaction with teachers were enabled by integrating a communication platform within a custom-made website [39] and encouraging pre-class student group discussions [51]. Since a working student–teacher relationship is known to enhance students' intrinsic motivation and performance [55], maintaining this line of communication open through all stages of the FC appears beneficial.

3.3. In-class phase

Discussions of preparatory material at the beginning of the session provided the opportunity for students to ask questions and clarify difficult concepts [24,26,27,29,34,35,38,46,51,52,54,56,57]. Where RATs had been included, in-class sessions commenced with a review of answers that helped students prepare for application by linking pre-session material with active classroom activities, which students rated highly [31].

The inclusion of demonstration videos in the pre-class phase obliviated the need for in-class demonstration and released time for hands-on practice during class [27,46,54]. However, any temporal advantage gained by this was offset by repeated in-class demonstration in two studies [47,58]. Groups for in-class teaching ranged from 4 students [38] to 30–35 students [34] with variable student to instructor ratio. Evans & Thiessen used a single instructor with a live video feed and individual screens for 80 students in groups of four to five in a FC teaching Ultrasound Scanning [27]. However, the reported cost-efficiency and knowledge gain were at the expense of lengthy sessions, limited teacher interaction and almost no direct feedback. In a flipped Emergency Medicine clerkship, students on themed shifts were responsible for locating and working with patients with an assigned chief complaint, sans any form of faculty support [30]. In this study, students did not do any better on assessment of flipped topics than traditionally taught ones, which illustrates that even in student-centred teaching, the 'guide by the side' remains indispensable. On the other hand, in a simulation-based mastery learning course of core CS which provided one-to-one feedback and demonstrated improved post-intervention skill performance, investigators reported spending more than 90 h training the 15 instructors for the course [53].

While supported students did better than those with little or no support [27,30], one to one supervision is costly and resource intensive [53]. Therefore, the implementation of a FC in resource-limited settings requires a balance between resource-efficiency and educational quality. Near-peer instruction has been shown to be as effective as expert instruction [59] and can be helpful [37,38]. Overall, what should be understood is that despite the increased student responsibility in a FC, support of faculty at all levels is essential for success.

Clinical simulation emulates the tenets of experiential learning providing an ideal setting for teaching TCS, clinical reasoning and problem solving within a safe environment [60]. Most of the studies in this review incorporated simulation-based training (Tables 2 and 3), some with simulated case scenarios to provide context and authenticity in line with adult learning principles [46,51]. Problem-solving and clinical decision-making were facilitated by either case discussions or virtual interactive simulated games [31,34]. Games and technology are not only favoured by students but are known to be useful in the provision of the strategic knowledge required for clinical problem solving [61]. This may have contributed to the self-perceived improvement in clinical performance reported by students in some studies [26,27,30,31,36,40].

Teamwork and peer collaboration were a central theme in 13 studies [24,26,31,34–36,38–40,45,51,52,54], which was reflected in student perceptions of improved teamwork and collaboration [31,36,51]. Students also valued the opportunity for interaction with instructors, as well as directly observed feedback because of the opportunities for scaffolding and error correction [24,27–29,31,35–37,47,51,53,54,56,58]. Debriefing and terminal feedback on observed performance [26], as well as on video recorded performance were also used to provide directed guidance [29,39]. Therefore, even if instructor–student interaction is limited, proper design can ensure superior interaction quality [31].

3.4. After class work

In TCS training, evidence suggests that providing opportunities for practice of learnt skills are helpful in developing competency and confidence [62]. The after-class phase of the FC can be used as a platform to offer students flexible, spaced out activities that provide opportunities to apply learnt skills [48]. Yet, only one study encouraged students to review material after class [51] and none provided opportunities for after-class practice, which is consistent with another review of the FC [48].

3.5. Educational outcomes

In general, the use of the FC for TCS training was viewed positively by students (Tables 2 and 3) as discussed in previous sections. Multiple areas of change in student attitudes were reported as shown in Table 4. Objectively measured knowledge scores in 12 studies showed either statistically significant knowledge gain or better post-intervention performance in the experimental groups over the control groups [24,26–28,32,34,38–40,45,51,56]. The exception was the flipped Emergency medicine clerkship described before [30]. In studies that measured both knowledge and skills gain, improved knowledge did not always predict improved skill [32,51].

Only 12 of the 25 studies measured skills acquisition [24,28,32,35,38,39,46,51–53,56,58]. Of these, 6 studies demonstrated a statistically significant increase in immediate, post-intervention skills acquisition [24,28,35,39,58] and 2 reported satisfactory post-intervention performance [38,38,53]. Such outcomes may be explained by the ability of the FC to support the complex interaction between psychomotor, cognitive and affective factors on skill performance [47]. Four studies showed no significant difference in immediate and interval skill performance [32,46,51,52]. Despite this, incidental views that were noted included time efficiency [27,31,46], resource efficiency [29,46] and cost-efficiency [29,45,51].

Tips for effective application of the flipped classroom in teaching TCS.

- The FC is more effective for short and long-term gains when carried out in controlled or simulated settings with a planned and structured approach.
- Orient stakeholders with the concept of the FC prior to implementation to ensure comfort and buy-in.
- Provide clear objectives and a plan for self-study with embedded self-assessments.
- Encourage peer and teacher-student dialogue throughout all stages of the FC.
- Design and customize preparatory material to complement in-class activity. A combination of conceptual and procedural knowledge delivered

Table 4. Changes in student attitudes and perceptions.

Attitude	Studies
Increased motivation	Ayandeh et al. [57]; Gong et al. [39]; Hwang & Chang [40]; Katz et al. [54]; Rodrigues, [29]; Zheng et al. [51]
Increased confidence	Ayandeh et al., [57]; Battaglia et al., [37]; Katz et al. [54]; Rodrigues [29]; Thomson et al. [24]; Uther et al. [26]
Decreased anxiety	Battaglia et al. [37]
Increased preparedness	G.Luchetti et al. [32]; Sezer & Elcin [35]
More likely to engage in Self-directed Learning	Belfi et al. [34]; Choi et al. [36]; Liebert et al. [31]

using audio-visual modalities are better than singular modalities. However, avoid lengthy material and supplement complex material with adequate scaffolding.
- Securing technical assistance to create preparatory material may ensure the sustainability of practice and once created, custom-made material can reposited, reused and shared.
- The quality of in-class instruction could be ensured by accommodating optimal in-class group sizes and the provision of immediate feedback.
- Incorporate after-class activities to promote the application and retention of learnt skills.

Understanding how and why different elements of a teaching intervention work can inform both the epistemological understanding and pragmatic improvement of its conduct [63]. This review focused on the *process* of the FC in order to outline how the FC can be *designed* effectively to teach TCS. Given the criticism about the non-equality of groups in comparative FC studies in ME [19], the educational superiority of the FC over other methods was not analysed. Our results indicate that various aspects of the design of the FC appear to benefit TCS training in ME by enabling cognitively efficient and optimal use of skills training time. Additionally, opportunities for repetitive practice and longitudinal training promote procedural competence [64]. Thus, it can be concluded that the overall structure of a pedagogically informed FC for TCS training in ME offers the opportunity to use evidence-based features in its' design to ensure optimal learning outcomes.

Although this review focused on TCS training, only just above one-third of the studies that were eligible for the review in terms of teaching a TCS, actually went on to objectively measure and report on skills acquisition. Future interventional studies using the FC should necessarily include an objective assessment of the skills taught to permit more meaningful and conclusive analysis. Support of this evidence base could be strengthened by the additional systematic collection of faculty views and perceptions to inform improvements.

Disclosure

As this study did not involve the collection of primary data, the authors deemed that ethical approval was not required.

Other disclosures

None.

Conflict of interest

We declare that we have no conflicts of interest, financial or otherwise to disclose.

Acknowledgments

The authors would like to acknowledge Dr. Lilani Ekanayake, retired Chair Professor of Community Dental Health, University of Peradeniya for proofreading the manuscript and sharing her valuable insight for amendments and improvement.

Appendix

Titles and geographic distribution of reviewed studies.

Country	Authors and year of publication	Tile of Paper
USA	Belfi et al., 2015	''Flipping'' the introductory clerkship in Radiology: impact on medical student performance and perceptions
	Heitz et al., 2015	Does the concept of the “Flipped Classroom” extend to the Emergency Medicine clinical clerkship?
	Boysen-Osborn et al., 2016	Flipping the advanced cardiac life support classroom with team-based learning: comparison of cognitive testing performance for medical students at the University of California, Irvine, United State
	Liebert et al., 2016	Student perceptions of a simulation-based flipped classroom for the surgery clerkship: a mixed methods study
	Reed et al., 2016	Simulation-based mastery learning improves medical student performance and retention of core clinical skills
	Katz et al., 2017	Teaching procedural skills to medical students: a pilot procedural skills lab
	Evans & Thiessen, 2019	Novel approach to introducing an Ultrasonography curriculum with limited instructor resources
	Ayandeh et al., 2020	Development of a pilot procedural skills training course for preclerkship medical students

(*continued on next page*)

(continued)

Country	Authors and year of publication	Tile of Paper
Korea	Kim & Jang, 2017	Flipped learning with simulation in undergraduate nursing education
	Beom et al., 2018	Flipped-classroom training in advanced cardiopulmonary life support
	Choi et al., 2021	Undergraduate nursing students' experience of learning respiratory system assessment using flipped classroom: a mixed methods study
Taiwan	Chiu et al., 2017	The effectiveness of a simulation-based flipped classroom in the acquisition of laparoscopic suturing skills in medical students—a pilot study
	Wu et al., 2018	Helps from flipped classroom in learning suturing skill: the medical students' perspective
	Hwang & Chang, 2020	Facilitating decision-making performances in nursing treatments: a contextual digital game-based flipped learning approach
China	Zheng et al., 2020	Flipped classroom approach used in the training of mass casualty triage for medical undergraduate students
	Gong et al., 2021	Application of blended learning approach in clinical skills to stimulate active learning attitudes and improve clinical practice among medical students
Australia	Thomson et al., 2011	Teaching medical students to resuscitate children: an innovative two-part programme
	Uther et al., 2019	Introducing early-phase medical students to clinical Paediatrics using simulation and a flipped-classroom
Canada	Khoury et al., 2020	Pre-clerkship Point-of-Care Ultrasound: image acquisition and clinical transferability
	Battaglia et al., 2021	A pre-clerkship simulation-based procedural skills curriculum: decreasing anxiety and improving confidence of procedural skill performance
Brazil	G. Lucchetti et al., 2018	Using traditional or flipped classrooms to teach “Geriatrics and Gerontology”? Investigating the impact of active learning on medical students' competences
Germany	Rohle et al., 2021	Practical teaching in undergraduate human and dental medical training during the COVID-19 crisis. Report on the COVID-19-related transformation of peer-based teaching in the Skills Lab using an Inverted Classroom Model
Japan	Nakanishi et al., 2017	The effects of flipped learning for bystander cardiopulmonary resuscitation on undergraduate medical students
New Zealand	Rodrigues, 2016	Use of the flipped classroom model in the clinical learning curriculum for third year nursing students
Turkey	Sezer & Elcin, 2020	Using traditional or flipped classrooms to teach “vascular access skill”: a pilot study to investigate the impact of the flipped classroom approach on students' competencies

References

[1] Elder A. Clinical skills assessment in the twenty-first century. Med Clin North Am 2018;102(3):545–58.

[2] Seale J, Knoetze M, Phung A, Prior D, Butchers C. Commencing technical clinical skills training in the early stages of Medical Education: exploring student views. Med Sci Educ 2019;29(1):173–9.

[3] Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. Acad Med 2004;79(10 Suppl):S70–81.

[4] Schmidmaier R, Eiber S, Ebersbach R, Schiller M, Hege I, Holzer M, et al. Learning the facts in medical school is not enough: which factors predict successful application of procedural knowledge in a laboratory setting? BMC Med Educ 2013;13:28.

[5] Nicholls D, Sweet L, Muller A, Hyett J. Teaching psychomotor skills in the twenty-first century: revisiting and reviewing instructional approaches through the lens of contemporary literature. Med Teach 2016;38(10):1056–63.

[6] Larsen DP. Planning education for long-term retention: the cognitive science and implementation of retrieval practice. Semin Neurol 2018;38(4):449–56.

[7] DeLozier SJ, Rhodes MG. Flipped classrooms: a review of key ideas and recommendations for practice. Educ Psychol Rev 2017;29(1):141–51.

[8] Abeysekera L, Dawson P. Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research. High Educ Res Dev 2015;34(1):1–14.

[9] Vogel D, Harendza S. Basic practical skills teaching and learning in undergraduate medical education—a review on methodological evidence. 33 GMS J Med Educ 2016;15(4): Doc64.

[10] Ge L, Chen Y, Yan C, Chen Z, Liu J. Effectiveness of flipped classroom vs traditional lectures in radiology education: a meta-analysis. Medicine 2020;99(40):e22430.

[11] Ramnanan CJ, Pound LD. Advances in medical education and practice: student perceptions of the flipped classroom. Adv Med Educ Pract 2017;8:63–73.

[12] Hurtubise L, Hall E, Sheridan L, Han H. The flipped classroom in medical education: engaging students to build competency. J Med Educ Curric Dev 2015;2. JMECD. S23895.

[13] Chen KS, Monrouxe L, Lu YH, Jenq CC, Chang YJ, Chang YC, et al. Academic outcomes of flipped classroom learning: a meta-analysis. Med Educ 2018;52(9):910–24.

[14] Hew KF, Lo CK. Flipped classroom improves student learning in health professions education: a meta-analysis. BMC Med Educ 2018;18(1):38.

[15] Xu P, Chen Y, Nie W, Wang Y, Song T, Li H, et al. The effectiveness of a flipped classroom on the development of Chinese nursing students' skill competence: a systematic review and meta-analysis. Nurse Educ Today 2019;80:67–77.

[16] Van Alten DC, Phielix C, Janssen J, Kester L. Effects of flipping the classroom on learning outcomes and satisfaction: a meta-analysis. Edu Res R 2019;28:100281.

[17] Chen F, Lui AM, Martinelli SM. A systematic review of the effectiveness of flipped classrooms in medical education. Med Educ 2017;51(6):585–97.

[18] Hughes Y, Lyons N. Does the flipped classroom improve exam performance in medical education? A systematic review. MedEd Publish 2017;6(100):100.
[19] Vanneman M, Baker K, Saddawi-Konefka D. Studies on the effectiveness of flipped classrooms: are we comparing apples to apples? Med Educ 2017;51(12):1293–4.
[20] Hu R, Gao H, Ye Y, Ni Z, Jiang N, Jiang X. Effectiveness of flipped classrooms in Chinese baccalaureate nursing education: a meta-analysis of randomized controlled trials. Int J Nurs Stud 2018;79:94–103.
[21] Tan C, Yue W-G, Fu Y. Effectiveness of flipped classrooms in nursing education: systematic review and meta-analysis. Chin Nurs Res 2017;4(4):192–200.
[22] Currie J, Thompson C, Grootemaat P, Andersen P, Finnegan A, Carter M, et al. A scoping review of clinical skill development of preregistration registered nurses in Australia and five other English-speaking countries. J Clin Nurs 2023;32(1–2):283–97.
[23] Green BN, Johnson CD, Adams A. Writing narrative literature reviews for peer-reviewed journals: secrets of the trade. J Chiropr Med 2006;5(3):101–17.
[24] Thomson NM, Campbell DE, O'Leary FM. Teaching medical students to resuscitate children: an innovative two-part programme. Emerg Med Australas 2011;23(6):741–7.
[25] Hudson A, Mclaughlin R, Miller S, Holland J, Blake K. Canadian medical schools' preclerkship paediatric clinical skills curricula: how can we improve? Paediatr Child Health 2020; 25(8):505–10.
[26] Uther P, Van Munster KA, Briggs N, O'Neill S, Kennedy S. Introducing early-phase medical students to clinical paediatrics using simulation and a flipped-classroom. J Paediatr Child Health 2019;55(9):1107–12.
[27] Evans DK, Thiessen MEW. Novel Approach to introducing an Ultrasonography curriculum with limited instructor resources. J Am Osteopath Assoc 2019;119(8):533–40.
[28] Kim H, Jang Y. Flipped learning with simulation in undergraduate nursing education. J Nurs Educ 2017;56(6):329–36.
[29] Rodrigues A, Zealand W. Use of the flipped classroom model in the clinical learning curriculum for third year nursing students. In: H. Paper presented at: tetipuranga–Growing capability: proceedings of the 2015 national tertiary learning and teaching conference; 2016. p. 83–8.
[30] Heitz C, Prusakowski M, Willis G, Franck C. Does the concept of the "flipped classroom" extend to the emergency medicine clinical clerkship? West J Emerg Med 2015;16(6): 851–5.
[31] Liebert CA, Mazer L, Merrell S, Lin DT, Lau JN. Student perceptions of a simulation-based flipped classroom for the surgery clerkship: a mixed-methods study. Surgery 2016; 160(3):591–8.
[32] Granero Lucchetti AL, Ezequiel ODS, Oliveira IN, Moreira-Almeida A, Lucchetti G. Using traditional or flipped classrooms to teach "Geriatrics and Gerontology"? Investigating the impact of active learning on medical students' competences. Med Teach 2018;40(12):1248–56.
[33] Anand A. Does the flipped classroom method enhance the learning of undergraduate medical students: a review. Texila Int J Bas Med Sci 2019;4(1):1–5.
[34] Belfi LM, Bartolotta RJ, Giambrone AE, Davi C, Min RJ. "Flipping" the introductory clerkship in radiology: impact on medical student performance and perceptions. Acad Radiol 2015;22(6):794–801.
[35] Sezer B, Elcin M. Using traditional or flipped classrooms to teach "vascular access skill": a pilot study to investigate the impact of the flipped classroom approach on students' competencies. Soc Sci J 2020:1–14.
[36] Choi J, Lee SE, Bae J, Kang S, Choi S, Tate JA, et al. Undergraduate nursing students' experience of learning respiratory system assessment using flipped classroom: a mixed methods study. Nurse Educ Today 2021;98:10466.
[37] Battaglia F, Ivankovic V, Merlano M, Patel V, Sayed C, Wang H, et al. A pre-clerkship simulation-based procedural skills curriculum: decreasing anxiety and improving confidence of procedural skill performance. Can Med Educ J 2021 Nov 1;12(5): 34–9.
[38] Khoury M, Fotsing S, Jalali A, Chagnon N, Malherbe S, Youssef N. Preclerkship point-of-care ultrasound: image acquisition and clinical transferability. J Med Educ Curric Dev 2020;7:2382120520943615.
[39] Gong J, Ruan M, Yang W, Peng M, Wang Z, Ouyang L, et al. Application of blended learning approach in clinical skills to stimulate active learning attitudes and improve clinical practice among medical students. PeerJ 2021;9:e11690.
[40] Hwang G, Chang C. Facilitating decision-making performances in nursing treatments: a contextual digital game-based flipped learning approach. Interact Learn Environ 2020:1–16.
[41] Scott K, Morris A, Marais B. Medical student use of digital learning resources. Clin Teach 2018;15(1):29–33.
[42] Guze PA. Using technology to meet the challenges of medical education. Trans Am Clin Climatol Assoc 2015;126:260.
[43] Ibrahim M. Implications of designing instructional video using cognitive theory of multimedia learning. Crit Q Educ 2012;3(2):83–104.
[44] King A, Boysen-Osborn M, Cooney R, Mitzman J, Misra A, Williams J, et al. Curated collection for educators: five key papers about the Flipped Classroom methodology. Cureus 2017;9(10):e1801.
[45] Boysen-Osborn M, Anderson CL, Navarro R, Yanuck J, Strom S, McCoy CE, et al. Flipping the advanced cardiac life support classroom with Team-based Learning: comparison of cognitive testing performance for medical students at the University of California, Irvine, United States. J Educ Eval Health Prof 2016;13:11.
[46] Nakanishi T, Goto T, Kobuchi T, Kimura T, Hayashi H, Tokuda Y. The effects of flipped learning for bystander cardiopulmonary resuscitation on undergraduate medical students. Int J Med Educ 2017;8:430.
[47] Wu J-C, Chi S-C, Wu C-C, Kang YN. Helps from flipped classroom in learning suturing skill: the medical students' perspective. PLoS One 2018;13(10):e0204698.
[48] Persky AM, McLaughlin JE. The flipped classroom–from theory to practice in health professional education. Am J Pharmaceut Educ 2017;81(6):118.
[49] Jang HW, Kim KJ. Use of online clinical videos for clinical skills training for medical students: benefits and challenges. BMC Med Educ 2014;14:56.
[50] Moreno R, Mayer R. Cognitive principles of multimedia learning: the role of modality and contiguity. J Educ Psychol 1999;91:358–68.
[51] Zheng Z, Yuan S, Huang M, Liao J, Cai R, Zhan H, et al. Flipped classroom approach used in the training of mass casualty triage for medical undergraduate students. Disaster Med Public Health Prep 2022;16(1):94–101.
[52] Beom JH, Kim JH, Chung HS, Kim SM, Ko DR, Cho J. Flipped-classroom training in advanced cardiopulmonary life support. PLoS One 2018;13(9):e0203114.
[53] Reed T, Pirotte M, McHugh M, Oh L, Lovett S, Hoyt AE, et al. Simulation-based mastery learning improves medical student performance and retention of core clinical skills. Simul Healthc 2016;11(3):173–80.
[54] Katz LM, Finch A, McKinnish T, Gilliland K, Tolleson-Rinehart S, Marks BL. Teaching procedural skills to medical students: a pilot procedural skills lab. Educ Health (Abingdon). 2017;30(1):79–83.
[55] Haidet P, Stein HF. The role of the student-teacher relationship in the formation of physicians. J Gen Intern Med 2006;21(1):16–20.
[56] Ayandeh A, Zhang XC, Diamond JF, Michael SH, Rougas S. Development of a pilot procedural skills training course for preclerkship medical students. J Am Coll Emerg Physicians Open 2020;1(6):1199–204.
[57] Röhle A, Horneff H, Willemer MC. Practical teaching in undergraduate human and dental medical training during the COVID-19 crisis. Report on the COVID-19-related transformation of peer-based teaching in the Skills Lab using

an Inverted Classroom Model. GMS J Med Educ 2021;38(1). Doc 2.
[58] Chiu HY, Kang YN, Wang WL, Huang HC, Wu CC, Hsu W, et al. The effectiveness of a simulation-based flipped classroom in the acquisition of laparoscopic suturing skills in medical students—a pilot study. J Surg Educ 2018;75(2):326—32.
[59] Khapre M, Deol R, Sharma A, Badyal D. Near-peer tutor: a solution for quality medical education in faculty constraint setting. Cureus 2021;13(7):e16416.
[60] Herrera-Aliaga E, Estrada LD. Trends and innovations of simulation for twenty first century medical education. Front Public Health 2022;10:619769.
[61] Kopp V, Stark R, Kühne-Eversmann L, Fischer MR. Do worked examples foster medical students' diagnostic knowledge of hyperthyroidism? Med Educ 2009;43(12):1210—7.
[62] Byrne AJ, Pugsley L, Hashem MA. Review of comparative studies of clinical skills training. Med Teach 2008;30(8):764—7.
[63] Yardley S, Dornan T. Kirkpatrick's levels and education 'evidence'. Med Educ 2012;46(1):97—106.
[64] Bosse HM, Mohr J, Buss B, Krautter M, Weyrich P, Herzog W, et al. The benefit of repetitive skills training and frequency of expert feedback in the early acquisition of procedural skills. BMC Med Educ 2015;15:22.