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ORIGINAL RESEARCH

Near-Peer Teaching in Conjunction with Flipped Classroom to Teach First-Year Medical Students Basic Surgical Skills

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Abstract

Background There is increasing evidence that students are completing medical school with insufficient surgical education. Near-peer tutoring and flipped classroom formatting may be used to enhance learning while simultaneously relieving faculty burden of teaching. Here, we qualitatively evaluate a 3-month course that integrates the use of near-peer teaching and flipped classroom formatting, with the goal of increasing first-year medical students' self-perceived confidence in performing basic sutures and knot-ties as well as interest in surgery.

Methods Twenty-one first-year medical students participated in a suturing and knot-tying course led by senior medical students. The course consisted of 2-h sessions held every 2 weeks for a total of five sessions. Students were sent publicly available videos prior to each session by which to learn the upcoming techniques and received live feedback from instructors during sessions. Questionnaires were completed pre-course and post-course.

Results Compared to pre-course ratings, post-course ratings of self-perceived confidence to perform various knot-ties and sutures all increased significantly ($p < 0.05$). All students stated that the course strengthened their desire to pursue a career in surgery. Student feedback of the course was overall positive.

Conclusions Near-peer teaching can be used in conjunction with flipped classroom to increase first-year medical students' self-perceived confidence in surgical suturing and knot-tying as well as interest in surgery. This curriculum may serve as an outline for student-led courses at other institutions.

Keywords Student education · Peer-assisted learning · Suturing and knot-tying · Education · Medical school education · Flipped classroom

Introduction

There is increasing evidence that students are completing medical school with insufficient surgical education (e.g., suturing and knot-tying) [1, 2]. This negatively affects the surgical competency of doctors within their first years of surgical residency. Moreover, early exposure to surgery through skill courses significantly increases student interest in surgery — these benefits have been demonstrated in students as early as their first and second years of medical school [3–5]. Thus, a lack of exposure to surgical practice during medical school may reduce the recruitment of future trainees to surgical residencies [4, 6, 7]. Earlier exposure is also beneficial in that it provides the student with more time to prepare for surgical rotations, build valuable connections with faculty, and prepare their application for residency [8–11]. Unfortunately, it is not always feasible for physicians to teach surgical techniques to junior medical students, as teaching surgical skills is labor intensive and requires a high teacher-to-student ratio [5, 6, 12].

Near-peer teaching (NPT) represents an alternative teaching approach that relieves the burden of traditional faculty-led teaching [13]. In this approach, the instructor is a person who is one or more years senior to another while being on the same level of educational training — for instance, senior medical students and junior medical students [4, 5, 14–16]. A large body of literature exists on

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NPT that spans across multiple domains, including general teaching, higher education, and, more recently, medical education [17]. Though a comprehensive review on NPT is beyond the scope of this paper, multiple randomized controlled trials, systematic reviews, quantitative studies, qualitative studies, and expert opinions have been published supporting the efficacy of NPT within medical education [16, 18–23]. There are distinct theoretical features of NPT that underlie the effectiveness of this approach. These include, but are not limited to, reduced educational distance between the teacher and learner, a less formal educational setting, and smaller learner group sizes [13, 24, 25]. Moreover, NPT is advantageous to the peer instructors themselves, as it provides an opportunity for students to develop teaching skills in a low-pressure environment while enhancing their own knowledge [15, 26, 27].

Similarly, flipped classroom (FC) has risen in popularity in recent years [28, 29]. In a traditional classroom, foundational knowledge is passively transferred to the student during class via lecture, with students then expected to apply this knowledge outside of class. In the FC model, students learn new material or techniques prior to class (for instance, via a video lecture), then use class time to put those concepts into practice [28]. Similar to NPT, the FC approach has been implemented across many subject domains and educational levels [30–32]. The majority of evidence argues that the FC approach draws its efficacy from enhancing students' cognitive learning outcomes, improving student motivation, and promoting more efficient student–teacher interactions inside the classroom [33–35]. The body of literature on the use of FC in the field of medical education has grown over the past year, and while there is an overall acceptance of its use, there exists a heterogeneity among studies regarding the effectiveness of the FC [29, 36–38]. Challenges inherent to the FC design include low self-regulated behaviors of some students, the failure of some students to properly schedule their time outside of class, and more required time to redesign courses as FC [34].

Specific to the domain of medical students learning surgical skills, multiple studies have described the efficacy of NPT [14, 39–45] as well as FC [29, 37, 46]. In a randomized control trial involving 60 third-year and fourth-year medical students, Pintér et al. demonstrated that NPT had a positive impact on students' development of suturing and knot-tying [13]. In a laparoscopic suturing course, Chiu et al. randomized 59 medical students to a FC or traditional learning approach — post-course, students in the FC group scored significantly higher on an objective assessment of surgical skills [46]. Though these studies have demonstrated the efficacy of NPT and FC as individual tools, the efficacy of a combined approach has not been evaluated. Moreover, none of the studies limited their population to first-year medical students only [3, 4]. Thus, we designed a 3-month course that integrated the use of both NPT and FC to teach first-year medical students basic surgical suturing and knot-tying. We describe the design, implementation, and qualitative assessment of this course, in which the goal was to increase medical students' self-perceived confidence to perform basic surgical skills as well as interest in surgery.

Methods

Instructors

Third-year medical students who had previously completed the course as well as general surgery residents from The Ohio State College of Medicine (OSUCOM) were recruited as instructors. Instructors were recruited via a mass email to all students who had previously completed the course, as well as all OSUCOM general surgery residents. Instructors were selected on a rolling basis. Instructors were not compensated. A senior general surgery resident was present at each session to supervise the instructors. All instructors received written instructions and an individual briefing prior to each workshop. Five instructors were present at each workshop for a teacher:student ratio of approximately 1:4.

Curriculum

Five sessions were held to cover basic surgical suturing and knot-tying techniques (Table 1). Sessions occurred every 2 weeks and were 2 h in length. All students were provided with a suturing gel pad (Ultrassist, Shanghuan, China), knot-tying board (Ethicon, Raritan, NJ, USA), 2–0 nylon suture thread (Ethicon, Raritan, NJ, USA), and instruments (Adson toothed forceps, Webster needle holder, suture scissors; Surgical Online, Dix Hills, NY) to take home. The same material was utilized at each session. Seven days prior to each session, students were provided with publicly available YouTube (San Mateo, CA, USA) videos to learn the upcoming technique(s) on their own time. Videos that were most representative of techniques used in the operating room were selected by the senior author (D.R.) based on his experience as a general surgeon at The Ohio State University. Links to the videos are provided in Table 2. At each session, students practiced the most recently learned techniques while instructors provided live feedback and instruction.

Participants

All first-year medical students at OSUCOM were sent an email inviting them to participate. Students who expressed interest were asked to fill out an essay-based application.

Table 1 Outline of course curriculum

Pre-course surveys distributed and completed prior to course start	
Session 1	One-handed knot-tie Two-handed knot-tie
Session 2	Handling suture instruments Instrument tie
Session 3	Simple running suture Simple interrupted suture Subcuticular suture
Session 4	Horizontal mattress suture Vertical mattress suture Deep dermal suture Figure-of-8 suture
Session 5	Review of all learned techniques
Post-course surveys distributed and completed within 2 weeks of course completion	

Students were selected based on expressed interest in surgical suturing and knot-tying as well as degree of interest in surgery; those who did not have prior suturing/knot-tying experience were preferred over those who did. The number of participants was limited to 21 due to precautions related to the number of instructors and school-specific COVID-19 guidelines.

Evaluation and Analysis

Students completed a questionnaire before the course and within 2 weeks following course completion. The pre-course questionnaire assessed demographics, handedness, previous surgical exposure, desire to pursue a surgical career, and self-perceived confidence to perform certain sutures/knot-ties. The post-course questionnaire included identical questions related to confidence and desire to pursue a surgical career; feedback regarding organization and efficacy of the course as it related to NPT and FC was also collected. Near-peer instructors were also administered a survey within 2 weeks following course completion. This survey assessed their comfort and confidence teaching the course. The survey also administered an open-ended question: "What did you enjoy about being a teacher for this course?". Responses were scored by 5-point Likert scales, multiple choice questionnaires, or free-text responses. For the Likert scales, a rating scale of 1 (extremely unconfident; strongly disagree), 2 (unconfident; disagree), 3 (neither confident nor unconfident; neutral), 4 (confident; agree), and 5 (extremely confident; strongly agree) was employed.

Two-tailed unpaired *t* tests were performed on the pre- and post-course confidence data. Statistical analyses were performed on Microsoft Excel (Microsoft, Redmond, WA, USA). Significance was set at $p < 0.05$.

Results

A total of 21 first-year medical students at The Ohio State University College of Medicine attended our suturing and knot-tying course. The pre-course questionnaire was completed by 21 students (100%), and the post-course questionnaire by 21 students (100%). Demographical information is summarized in Table 3. The class consisted of 12 females (57%) and eight males (38%), with one student declining to respond. Most students identified as Caucasian (48%), Asian

Table 2 Links to the publicly available videos that were sent to students prior to each session

Skill	Video link
One-handed knot-tying	https://www.youtube.com/watch?v=uFJbTbjeU4Y
Two-handed knot-tying	https://www.youtube.com/watch?v=o8OqxTGaS7o
Handling suture instruments	https://www.youtube.com/watch?v=2HC7zM3D59Q&t=258s
Instrument tie	https://www.youtube.com/watch?v=wbpQhiNDxvo
Simple running suture	https://www.youtube.com/watch?v=ODZtJL_gb4E
Simple interrupted suture	https://www.youtube.com/watch?v=yWrm2MAfPUo
Subcuticular suture	https://www.youtube.com/watch?v=RN991nUXhC4
Horizontal mattress suture	https://www.youtube.com/watch?v=EZ4L9PC7mj0
Vertical mattress suture	https://www.youtube.com/watch?v=ZX8ccaqiuXQ
Deep dermal suture	https://www.youtube.com/watch?v=NZywvGtTXb4
Figure-of-8 suture	https://www.youtube.com/watch?v=l9ZUbg8_KE8

Table 3 Participant demographic information

Gender	
Male	8 (38%)
Female	12 (57%)
Other	1 (5%) — preferred not to respond
Race	
Asian	5 (24%)
White	10 (48%)
Multiracial	5 (24%)
Other	1 (5%) — no response
Hand dominance	
Right	19 (90%)
Left	1 (5%)
Ambidextrous	1 (5%)
Prior experience	
Surgical knot-tying	4 (19%)
Suturing	2 (9.5%)
Scrubbed in during a surgery	5 (24%)

(24%), or multiracial (24%). Regarding hand dominance, 19 students (90%) were right-handed, one student (5%) was left-handed, and one student (5%) was ambidextrous. Two students (10%) had prior suturing experience (e.g., suturing pad and surgical technician) and four students (19%) had previous surgical knot-tying experience (e.g., interest group workshops and self-taught).

Prior to the course, most students (95%) expressed above average or extreme confidence that they would consider a future career in surgery. Despite this, the majority (81%) were extremely unconfident in their ability to suture. Pre-course and post-course ratings of self-perceived confidence are summarized in Fig. 1 and Table 4. Compared to pre-course ratings, post-course ratings of self-perceived confidence to perform knot-ties (one-handed, two-handed, surgeon's knot) and sutures (simple running, subcutaneous, deep dermal, vertical mattress, horizontal mattress) all increased significantly ($p < 0.005$).

Feedback for the course was very positive. All students stated that the course strengthened their desire to pursue a career in surgery and that they would strongly recommend the course to a colleague. All students strongly agreed that they were taught in a relaxed environment. All students strongly agreed that instruction from senior medical students benefitted their learning. Notably, 16 students (76%) agreed or strongly agreed that they felt prepared to start their surgical clerkship, compared to zero students at the start of the course. All students agreed or strongly agreed that the course was well paced and well organized. Regarding use of

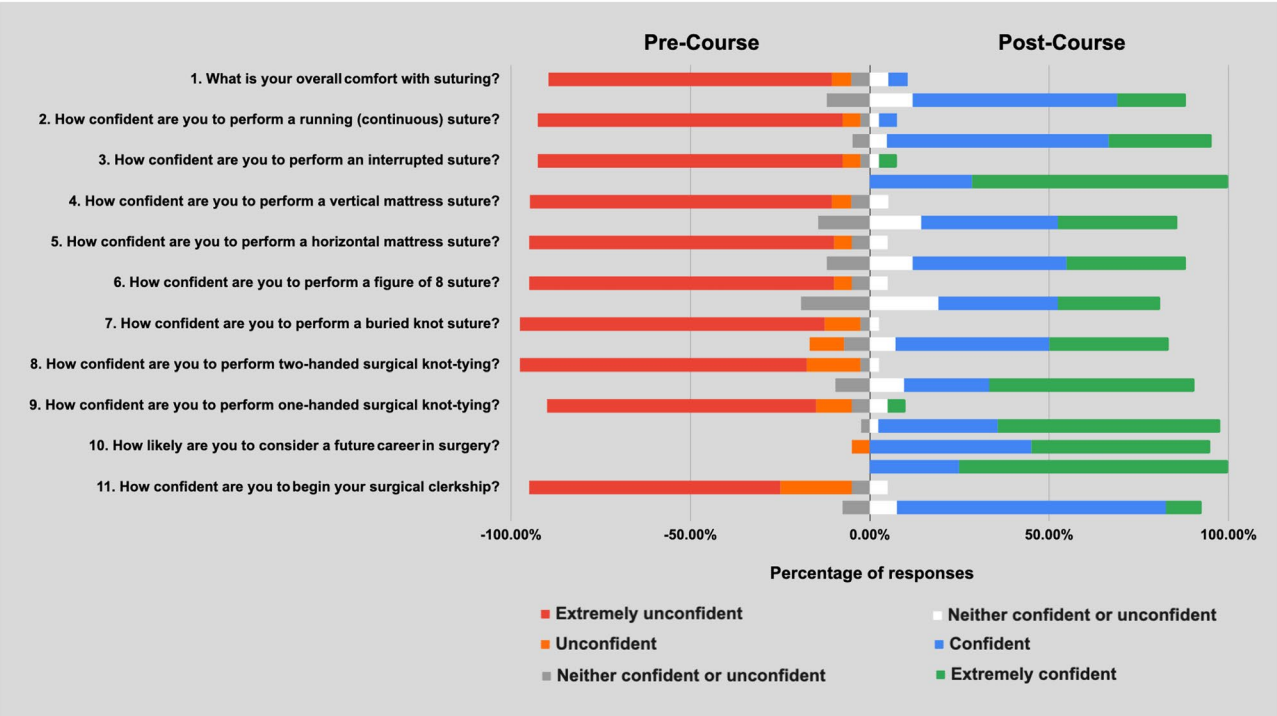

Fig. 1 Pre-course and post-course survey responses. A Likert scale showing students' overall pre- and post-course confidence levels. Pre-course responses are on the left and post-course responses are on the right. Questions target students' overall confidence with suturing, confidence with performing types of sutures (running, interrupted, vertical and horizontal mattress, figure of 8, buried knot) and knot-ties (one- and two-handed), considering surgery as a future career, and confidence to begin surgical clerkship

Table 4 Pre-course versus post-course survey responses. Average Likert scores for responses to pre-course and post-course survey questions are shown. A Likert score rating scale of 1 (extremely unconfident; strongly disagree), 2 (unconfident; disagree), 3 (neither confident nor unconfident; neutral), 4 (confident; agree), and 5 (extremely confident; strongly agree) was employed

	Mean Likert score		
	Pre-course	Post-course	*p*-value
What is your overall comfort with suturing?	2.1	7.4	$p < .001$
How confident are you to perform a running (continuous) suture?	1.7	7.8	$p < .001$
How confident are you to perform an interrupted suture?	1.5	8.8	$p < .001$
How confident are you to perform a vertical mattress suture?	1.5	7.4	$p < .001$
How confident are you to perform a horizontal mattress suture?	1.6	7.5	$p < .001$
How confident are you to perform a figure of 8 suture?	1.5	7	$p < .001$
How confident are you to perform a buried knot suture?	1.6	7.5	$p < .001$
How confident are you to perform one-handed surgical knot-tying?	2	8.2	$p < .001$
How likely are you to consider a future career in surgery?	8.3	8.8	$p > .05$
How confident are you to prepare your surgical clerkship?	2	7.5	$p < .001$

the FC format, most students either agreed (57%) or strongly agreed (29%) that they felt confident in their skills learned in this format. Similarly, most students either agreed (33%) or strongly agreed (38%) that they preferred the FC format over a traditional format, with a small minority disagreeing (10%). No students reported that the FC format negatively affected the quality of their education. In the free-text response, recommendations for improvements included using more realistic practice material ($n = 3$), having a review session at the start of each class session ($n = 3$), and decreasing the time between sessions ($n = 2$). Regarding the near-peer instructors, all five instructors agreed or strongly agreed that they felt comfortable teaching, that students benefitted from their teaching, and that they felt confident in their suturing/knot-tying skills. When asked what they enjoyed about being a teacher for the course, four instructors (80%) mentioned adapting to different learning styles, three (60%) commented on the opportunity to improve their suturing ability, and three (60%) commented on the opportunity to assist fellow students.

Discussion

Suturing and knot-tying are fundamental surgical skills; however, many medical schools provide inadequate training [1]. In a review of 23 medical schools in the UK, Davis et al. found that < 25% of medical schools taught suturing and/or knot-tying as part of their curriculum [1]. At our institution, the only suturing and knot-tying training medical students receive as part of the medical school curriculum is a 2-h course prior to starting their surgical clerkship, which the authors believe is inadequate to prepare students for real patients. This lack of training is supported by our findings. Notably, while > 90% of students in our course desired to enter a surgical career, none felt confident in their ability to suture/knot-tie or start their surgical clerkship. Moreover, demand for the course was extremely high, with 106 students applying for 21 available spots within 1 h of registration opening. This demonstrates that while demand for practical surgical skills teaching is high, these needs are not currently being met at our institution.

As a result of our course that utilized both NPT and FC, all students showed a significant increase in their confidence to perform fundamental suturing and knot-tying techniques. Moreover, all students felt that they were taught in a relaxed environment and that instruction from the near-peer tutors greatly benefitted their learning. One explanation for the success of NPT in the literature is that it utilizes cognitive congruence — that is, learners can better relate to the teacher [24, 47]. Because the near-peer instructors have recently had similar experiences as the learner, they can more easily identify and relate to where the learner may be struggling [48, 49]. That fact that NPT creates a relaxed and open learning environment is also important, as this encourages learners to come forward with questions when they are struggling [25, 49]. Near-peer teaching is beneficial to the instructors as well, as the student-instructors can improve their teaching skills and solidify their knowledge on a topic [50, 51]. Indeed, research has suggested that teaching helps students become better learners themselves [50, 51]. Interestingly, when we asked peer instructors what they enjoyed about being a teacher for our course, without being specifically prompted, the majority of peer instructors cited the opportunity to improve their suturing ability, adapting to different learning styles (improving their teaching skills), and/or the opportunity to assist other students.

The integration of a FC format in our course allowed students to utilize class time more efficiently by practicing their skills with live feedback from instructors, rather than spending class time learning skills for the first time. In our course, all students agreed that they felt confident in their skills learned in this format, the vast majority (90%) agreed that they preferred the FC format over the traditional format, and no students felt that the FC format negatively affected their education. This is in line with multiple studies in the

literature, which demonstrate that students tend to have overwhelmingly positive perceptions of FC [29, 37, 46, 52, 53]. The reasons underlying the efficacy of the FC approach have been related to enhancing teaching and learning conditions for students, improving students' cognitive learning outcomes, skill development, and overall motivation [36, 53]. Moreover, the FC has been argued to improve students' motivational "needs" for engaging in the learning process [54]. According to the Self-Determination Theory, these "needs" relate to autonomy (the need to engage with tasks in an autonomous manner), relatedness (the need to engage in tasks that allow collaboration and communication with other students), and competence (the need of students to feel capable to successfully engage in the learning process) [26]. Though the exploration of these underlying factors was beyond the scope of the current study, they may explain the efficacy of our course design.

Early exposure to surgical skill courses has been shown to increase student interest in surgery. Patel et al. demonstrated that after attending a student-organized half-day surgical skills workshop, 29 of 33 first- and second-year medical student attendees reported an increased interest in surgery [4]. In our course, all attendees reported that participating in the course significantly increased their interest in surgical careers. Moreover, the fact that all students were first-year medical students suggests that students do not need to wait until later into their medical education to engage in such courses. Encouragingly, despite concerns of too few women and racial minorities entering surgical careers, the majority of course participants were female (60%) or identified as a racial minority (55%). This early introduction and exposure for women and underrepresented minorities is important for encouraging women to ultimately enter the surgical field and increase representation in these fields.

It was notable that 76% of the students agreed or strongly agreed that they felt prepared to start their surgical clerkship after completion of our course, compared to zero students at the start of the course. This is in line with prior literature, which have shown that introductory surgical workshops increase medical students' confidence to start their surgical rotations or sub-internships [4, 55, 56]. Moreover, evidence exists that these improvements may persist into third-year surgical rotations. In a study by Manning et al., first-year medical students were given a daily opportunity over a 3-week period to practice suturing on cadaver-patients by closing superficial incisions with interrupted sutures and instrument ties [56]. When surveyed during their third-year surgical rotation, students who participated in the course were found to be significantly more confident when suturing patients and also sutured more frequently compared to their peers [56]. Of note, this course did not utilize NPT or a FC approach [56].

It is important to note that NPT and FC are not without drawbacks. One major drawback of the FC approach is that some students may not properly schedule their time outside of class to appropriately utilize the pre-course preparatory material [34, 53]. Indeed, suggestions that students in our course provided were to include "tests" throughout the course to ensure mastery of skills, as well as holding a brief overview of the skills at the start of each session. We agree that the integration of these suggestions would help to minimize the issue of low self-regulated behavior and ambiguity of pre-course material utilization [34]. However, Wu et al. also argued that medical students should be considered "mature learners," meaning that they are active and constructive learners who can monitor, control, and regulate their own cognition, motivation, behavior, and features of learning [29]. Regarding NPT, major drawbacks include the issue of poor resources as well as knowledge and training deficits of the instructors [57]. Indeed, instructors in our course did not undergo formalized training. Nevertheless, all five instructors agreed that they felt comfortable teaching and confident in their suturing/knot-tying skills.

We hope that our curriculum may serve as an outline for student-led courses at other institutions. Use of NPT and FC is feasible, though future courses should consider feedback received from our students. Namely, the use of "tests" throughout the course is a reasonable suggestion. Additionally, a complaint that students voiced regarding our course was that they would have liked to practice with better suturing material (for instance, pig feet instead of silicone pads). If possible, courses should strive to utilize more effective practice material for suturing. It is also reasonable to shorten the length of time between sessions. We utilized 2 weeks between sessions in an attempt to optimize long-term retention of material, though many courses in the literature have been shorter [41, 44, 58]. Finally, it may be beneficial to have student-instructors engage in formalized training prior to teaching, with the goal of optimizing NPT efficacy.

Limitations

Our study is limited by a small sample size ($n = 21$), and future studies should consider combining data from multiple sessions in order to increase sample size. The selection bias of attending students may also impact the data, as those who attended were more likely to already be interested in surgery. Limitations inherent to NPT and the FC approach may also have affected our study [57]. Further studies should be undertaken to objectively evaluate skills acquired through the course, in addition to long-term retention of skills.

Conclusion

Near-peer teaching can be used in conjunction with flipped classroom to increase first-year medical students' self-perceived confidence in surgical suturing and knot-tying as well as interest

in surgery. This curriculum may serve as an outline for student-led courses at other institutions.

Declarations

Ethics Approval The Ohio State University exempted this study from IRB approval.

Consent to Participate All participants provided written informed consent via Google forms to participate in this study.

Conflict of Interest The authors declare no competing interests.

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