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ORIGINAL RESEARCH

The Flipped Classroom: Addressing the Ultrasound Curriculum Gap in Undergraduate Medical Education

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Abstract

Purpose Point-of-care ultrasonography has been shown to improve patient outcomes in a wide array of medical specialties. In response, many medical schools have added ultrasonography into their standard curriculum, while others note the additional time and cost of these courses are barriers to their implementation. The purpose of this study was to evaluate the implementation of a new medical school ultrasound curriculum using the flipped classroom model with the primary aim to assess students' adoption of the flipped classroom model and their perception of the educational benefit of this ultrasound curriculum design.

Method One hundred seventy-nine first year medical students were given access to online ultrasound resources to review prior to five, 1-h, hands-on scanning sessions. After the course concluded, student perception of the flipped classroom design was obtained.

Results On average, 84% of students reviewed the material prior to each session. Student satisfaction with this curriculum design was positive, with the most favorable response occurring when replying to, "This activity was preferable to the traditional lecture format."

Conclusion Our study demonstrates that the flipped classroom model is an effective and preferable way to expand undergraduate medical education to include ultrasonography without adding to an already full lecture burden.

Keywords Undergraduate medical education · Ultrasonography · Computer-based · Flipped classroom

Introduction

Ultrasound imaging has seen tremendous growth over the past few decades. Many studies have shown that it regularly improves patient outcomes due to its diagnostic capabilities within a wide array of specialties [17] and quick, bedside utility. [9, 15, 20, 23, 25] Not only does ultrasonography improve patient mortality, but it has been shown to increase success rates of most invasive procedures including vascular access, paracentesis, thoracentesis, joint space access, and abscess drainage [16]. As the advantages continue to grow, multiple medical specialties are now applying point-of-care ultrasound imaging more frequently within their respective fields.

Similarly, a growing number of medical schools have implemented ultrasound training into the standard undergraduate medical education (UME). The rationale for incorporating ultrasound imaging earlier in medical education is that it enhances physical exam skills [3, 6, 10, 13], improves understanding of anatomy [11, 26], and facilitates competency in performing diagnostic and procedural ultrasound exams [7, 12]. The scope of curricula growth in UME was highlighted in a survey of US allopathic medical schools by Bahner et al. [4]. Of 82 responses, the majority (62.2%) reported having implemented ultrasound education into their curriculum, with the majority (78.9%) agreeing that ultrasound teaching should be a standard part of the medical school curriculum. The largest reported barriers to the widespread implementation of ultrasound education were perceived lack of space in the time set aside for the standard curriculum and lack of financial support for a new ultrasound program.

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Despite the widespread support for ultrasound education, the implementation of such curriculum changes within US medical schools remains a challenge, as medical school curricula are already on the verge of change. With the recent resurgence of interest in reverting back to the 3-year medical school design, medical school curricular administrators are focusing more on cutting down components of medical curriculum, rather than adding new ones [21]. Proponents of this change cite medical students' growing debt and the projected shortage of up to 90,000 physicians by 2025 [8]. A recent survey of 120 medical schools in the USA reported at least 30% are considering shortening to a 3-year program, while a few schools already boast the option of being admitted to a 3-year cohort [1].

The addition of ultrasound curricula in UME is at odds with an already full curriculum schedule and desires to further cut curriculum time. Additionally, ultrasound education is unique in that it necessitates both didactic and hands-on training that address both the interpretative and technical aspects of the exam. As a result, efficient methods for implementing ultrasound curriculum are critical for future success.

Before 2000, the vast majority of medical schools relied on the traditional classroom model to teach students the medical background prior to continuing their education in the clinical setting. The traditional classroom is a model of one-way dissemination of knowledge from the expert to the student, primarily relying on rote memorization and application of the new information outside of the classroom. Many argue that this model fails to optimize each student's education given the variety of learning styles [14]. As an alternative to the traditional classroom model, J. Wesley Baker described a "flipped" classroom model, where students take control of their learning by studying course material outside of class and participate in applied problem solving using that material while in class [5].

Since 2000, many graduate medical education (GME) studies have shown this model to be well perceived by students and professors, as well as a similarly efficacious teaching alternative when compared to traditional classroom teaching [18, 19, 24]. Several studies have been conducted to determine the flipped classroom model's effectiveness in medical education, spanning multiple specialties and training levels. These have not only reported that flipped classroom cohorts achieved similar written test and objective structured clinical examination scores compared to their traditional classroom counterparts but also reported a similar, if not better, perception of benefits to their education [7, 12, 22].

While the above studies have applied the flipped classroom design to GME, very little research has been devoted to studying this model to ultrasound education in the UME setting. The purpose of this study was to describe implementation and evaluation of a new medical school ultrasound curriculum using the flipped classroom model. Our aim was to assess students' adoption of the flipped classroom model and their perception of the educational benefit of this ultrasound curriculum design.

Method

One hundred and seventy-nine first year medical students enrolled at the University of Colorado School of Medicine participated in the ultrasound curriculum. Students were able to access pre-scanning didactic materials either via online video modules or via iBooks™. Students self-selected which type of pre-scanning materials they would review. The video modules consisted of still ultrasound images, clips of real-time ultrasound videos, and animations, with an associated audio lecture in the background. The iBooks™ consisted of the same still ultrasound images, clips of real-time ultrasound videos, and animations, but with text descriptions of the material in lieu of audio. The video modules and iBooks™ covered content in five areas: (1) introduction to ultrasound, (2) upper and lower musculoskeletal anatomy, (3) cardiovascular anatomy, (4) abdominal anatomy, and (5) head and neck anatomy. Each of the five content areas had specific goals and learning objectives that were covered in the pre-scanning didactic materials and were distributed to the instructors and students before the scanning sessions. Students were then required to complete a five-question individual readiness assurance test (iRAT) covering the flipped classroom educational content for each session. Assessments were open until 8:00 a.m. of the day of the scanning session. All students subsequently participated in five, 1-h, hands-on ultrasound teaching sessions covering: (1) basic principles and imaging techniques, (2) musculoskeletal anatomy, (3) cardiovascular anatomy, (4) abdominal anatomy, and (5) head and neck anatomy. The online resources were available 24 h a day up to the morning of the associated ultrasound session. At the start of each ultrasound session, participants indicated if they had reviewed either of the resources prior to class. Students were divided randomly into small groups (2–3 students/scanning group) and given hands-on instruction by Emergency Medicine faculty, Emergency Medicine Ultrasound fellows, Emergency Medicine residents, or fourth year medical students who had completed a clinical ultrasound elective [2]. The scanning sessions covered the goals and objectives for each of the different content areas and one faculty member proctored the scanning sessions to ensure that the content was taught uniformly across the different groups. Following the last scanning session, students completed a post-curriculum survey assessing their perception of the flipped classroom model. Our program evaluation protocol was evaluated by the Colorado Multiple Institutional Review Board and determined to be exempt from full ethics board review.

Table 1 First year medical students' pre-session preparation responses

Session topic	Students participating	Reviewed material prior	Reviewed modules	Reviewed iBooks™	Reviewed both
Introduction	174	171(98)	114(66)	42(24)	14(8)
Musculoskeletal	179	168(93)	103(61)	63(38)	2(1)
Cardiac	178	170(96)	106(60)	60(34)	3(2)
Abdominal	175	169(97)	115(68)	50(30)	4(2)
Head/neck	171	160(94)	88(55)	69(43)	3(2)
Average	175	168(96)	105(63)	57(34)	5(3)

Values are presented as the number of students per category (% of total)

Results

In the fall of 2015, 179 first year medical students participated in an ultrasound curriculum created using the flipped classroom method. On average 175 students participated in the ultrasound sessions, and 96% (168/175) reported reviewing the materials prior to class (Table 1). While the majority of students reviewed the video modules at the beginning of the five-session course, this number steadily decreased over time. However, the number of students reviewing the iBooks™ increased over time. The average number of attempts to achieve 100% on the pre-session assessments was 3.57 with a standard deviation of 2.92 (Table 2).

The response rate for the student satisfaction survey on the flipped classroom design was 84% (151/179). Overall, the students perceived the course well, with the highest scores recorded for the statement "this activity was preferable to the tradition lecture format" (Table 3).

Limitations

Our study has several limitations. We did not create a subgroup of students who were taught ultrasound via the traditional classroom model. However, the majority of UME is based on this format, and it is likely that students have had enough general exposure to the lecture-based model to form an educated opinion for which they prefer. In addition, we did not assess how well the online content prepared the students for the hands-on scanning sessions. While students completed an iRAT after reviewing the didactic content, it was a formative evaluation with students prompted to retake the questions until they achieved 100% correct responses. Other than direct observation by the instructors, we did not assess the student's proficiency during or after the scanning session. This, as well as a direct comparison to lecture-based teaching, should be addressed in future studies.

Students were given unlimited access to both online resources, but their individual time needed to complete the didactic content was not recorded. Thus, it is unclear whether this method of education is a more efficient use of their time, or if we are simply shifting the curriculum hours from the lecture hall to their personal study time. Additionally, the students self-reported whether they reviewed the content and which method they utilized.

While we created two separate online resources for students to choose between based on their learning styles, the iBooks™ format required access to an iPhone operating system (iOS) device. We did not collect data on whether students had access to an iOS device and whether they felt this was a barrier to their learning. In addition, there were slight variations in the content offered within the iBook™ and the modules. The images, videos, and animations were identical; however, the iBook™ contained additional text that was not explicitly spoken in the module. While acquiring access to an iOS device may have been a barrier for some students, the ability to make several different modes of information dissemination available for students to choose based on their learning styles simulates the benefits of using the flipped classroom design.

Table 2 First year medical students' pre-course assessment results

Session topic	Students participating	Mean no. of attempts until 100% achieved ± SD
Introduction	182	3.50 ± 3.45*
Musculoskeletal	178	2.69 ± 1.50*
Cardiac	179	4.13 ± 3.21*
Abdominal	180	2.99 ± 2.21
Head/neck	182	4.52 ± 3.03

*One student was excluded from these results as their total attempts were > 30 SD from the mean

Discussions

Overall, the flipped classroom model is growing in popularity and utility for a wide array of medical specialties. This is due

Table 3 First year medical students' satisfaction with the flipped classroom design

Question	Response options					Sample size	Mean ± SD
	1	2	3	4	5		
This activity is useful preparation for the ultrasound scanning sessions.	3(2)	14(9)	38(25)	67(45)	29(19)	151	3.70 ± 0.95
This activity was preferable to the traditional lecture format.	3(2)	13(9)	31(21)	49(32)	55(36)	151	3.93 ± 1.05
I was satisfied with this activity.	2(1)	15(10)	34(22)	69(46)	31(21)	151	3.74 ± 0.94
The flipped classroom format should be expanded to other curricula.	7(5)	8(5)	54(36)	46(30)	36(24)	151	3.64 ± 1.05

Values are presented as the number of responses per question (% of total)

Responses: 1 Strongly disagree, 2 Disagree, 3 Neither agree nor disagree, 4 Agree, 5 Strongly agree

to a number of studies that compared it to lecture-based teaching and have shown it to have comparable effects on test scores [7, 19, 22], makes the material more easily disseminated to learners [7], and is usually preferred when compared to the traditional classroom model [18, 19, 24].

These studies conclude that the flipped classroom model, when applied to graduate medical ultrasound education, is preferred over traditional lectures [12, 22] and significantly decreases course preparation time without adding extra cost [7]. While these studies show promise for the flipped classroom's role in ultrasound, further research is needed to fully explore its role within UME.

Our study is unique in that it is the first, to our knowledge, to report on the implementation of a flipped classroom model for teaching pre-clinical ultrasound to an entire medical school class. We found that the majority of students reported that the flipped classroom model for ultrasound education was not only well-perceived, but was preferable to the traditional classroom model. This result has important implications for UME curriculum, which dedicates a large portion of time to the format of lecturer and passive learner.

As medicine continues to evolve, UME will need to evolve as well. The increasing complexity of medical specialties and growing utility of ultrasound for diagnostic and procedural purposes has created a need for curriculum expansion to cover this important skill. However, curriculum changes must be implemented in a way that does not significantly increase students' debt burden or required class time. Our study supports the use of the flipped classroom model as a way to effectively expand UME to include ultrasound training without adding significantly to an already full lecture schedule.

Conclusion

Our study demonstrates that the flipped classroom model is an effective and preferable way to expand undergraduate medical education to include ultrasonography without adding to an already full lecture burden.

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