The Impact of the Flipped Classroom Pedagogical Approach in Graduate Medical Education

Thesis

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By

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Abstract

Background

The flipped classroom, an educational alternative to the traditional lecture, has been widely adopted by educators at all levels of education and across many disciplines. In the flipped classroom, learners prepare in advance of the face-to-face meeting by learning content material on their own. Classroom time is reserved for application of the learned content to solving problems or discussing cases. Flipped classroom instruction has become increasingly common in graduate medical education (GME). The Ohio State University Department of Emergency Medicine Residency Program replaced most residency program lectures with small group discussions using the flipped classroom model. The overall purpose of this thesis involves a detailed profile of the use of the flipped classroom in the GME setting, an assessment of the current status of research quality, and an evaluation of the effects of the flipped classroom pedagogical approach on emergency medicine learner performance.

Methods

A systematic literature search of the major health and social science databases was performed. Articles were screened to ensure they described use of the flipped classroom method in an ACGME accredited residency program and included research outcomes. Resulting articles were analyzed, described and evaluated for research quality using the Kirkpatrick Framework and the Medical Education Research Study Quality Instrument (MERSQI). Additionally, a cross cohort study of emergency medicine residents from entering classes of 2011 through 2015 was

performed. The study compared residents who experienced the lecture-based curriculum to residents in the new flipped classroom curriculum using paired comparisons (independent t-tests) on in-training exam scores while controlling for program year level. Results of the evaluation of various program components were also compared.

Results

22 articles were identified. Five were only indirectly related to flipped classroom methods. Most studies reported Kirkpatrick Level outcomes. Studies involving student opinions were generally positive. Pre-posttest studies resulted in large positive improvements in knowledge or skills attainment. Control group study results ranged from large positive (1.56) to negative effects (-.51). Average MERSQI scores 12.1 (Range=8.5-15.5) were comparable to GME research norms. No differences between cohorts on in-training examination scores were observed. Small group methods were rated the same across program years. Two program components in the new curriculum, an updated format of both adult and pediatric case conferences, were rated significantly higher on program quality. In preparation for didactics, residents in the new curriculum report spending more time, on average with outside learning materials, including almost twice as much time reviewing textbooks.

Conclusions

Because the flipped classroom in GME has been implemented in a variety of ways and studied with a variety of methods, research results are variable. While residents express a positive attitude toward flipped classroom learning, shortcomings were reported. About half the studies comparing the flipped to the traditional classroom reported better achievement. The flipped classroom had no effect on in-training examination scores. Residents estimate spending more time with outside learning materials in the new curriculum. Additional studies with more

sensitive assessment instruments are needed to identify potential differences in educational efficacy between the flipped classroom and traditional lecture method.

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Fields of Study

Major Field: Masters of Arts Degree in Education Studies with a Specialization in Biomedical Education

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Chapter 1. Introduction

Introduction

Medical education has been shifting from traditional, lecture-based teaching to approaches that promote higher-order thinking and active learning.[1] Medical educators are constantly scouring the medical education and social science literature for innovative and efficient pedagogical approaches to educate this population of adult learners. Active learning promotes increased student engagement with the ultimate goal of obtaining higher-order thinking on Bloom's Taxonomy such as analysis and evaluation.[10] One particular active learning pedagogical approach, the flipped classroom method, will be critically evaluated in this thesis study.

Within this particular chapter of the thesis presentation, the author will begin by outlining the background of the topic, and illustrating the problem and research questions to be determined by this research study. The thesis will then address the methodology and theoretical framework, while defining important terms used throughout the research study. This chapter will conclude with a presentation of the study significance and the assumptions and limitations associated with this particular research study evaluating the flipped classroom pedagogical approach when compared to traditional lecture-based instruction in graduate medical education.

Background

The lecture has long been the primary teaching method used for graduate medical education.[1] Because the lecture can be performed with a large student-to-teacher ratio, it is considered an efficient method of teaching.[1-2] The effectiveness of the traditional lecture as a teaching method has been called into question due to the lack of engagement by the learner.[2-3] The lecture puts the responsibility for the learning in the hands of the teacher, who is able to precisely regulate both the sequence and depth of content coverage. Participation on behalf of the learner is limited to listening, taking notes, and in some cases, asking clarifying questions.

Medical education has been shifting from traditional, lecture-based teaching to approaches that promote higher-order thinking and active learning.[1] One particular approach, the flipped classroom, has become increasingly popular in higher education, including medical education.[2] In this educational pedagogy, foundational content materials are studied by the learner independently through pre-classroom activities such as reading an article or textbook chapter, watching a multimedia presentation, or listening to a lecture in advance of classroom time. The classroom is reserved for applying foundational content knowledge in small group discussions involving clinical cases or more generic problem solving. The flipped classroom is student-centered. Learning is driven by the learners but guided or facilitated by experienced educators. Conversely, in the traditional classroom, foundational content material is transmitted to learners through lectures, which then requires review and reinforcement through study after class.[3-4]

Advances in technology as well as the search for more effective approaches to teaching seem to be driving the shift to a flipped classroom.[5] Active, self-directed learning, a necessary component of the flipped classroom learning model, is consistent with the needs graduate medical education learners.[4] Additionally, this model is consistent with both social, behavioral, and constructivist learning theories.[6-7] Group collaboration encourages modeling, scaffolding, and feedback that engage learners, and facilitates the integration of new knowledge with old.[8] Compared to the traditional lecture, the flipped classroom promotes higher levels of cognitive processing as defined by Bloom's Taxonomy.[8-10] As a result, increasing numbers of educators have adopted the flipped classroom across a variety of educational settings.[11-19]

Literature on the flipped classroom has proliferated rapidly across health sciences education since its inception in 2007.[20] Numerous articles originate from pharmacy, nursing, or veterinary medicine education programs.[3,7,12,21-29] Both a recent systematic review and a meta-analysis covering the flipped classroom in medical education yielded very few articles on graduate medical education.[3,30] Although many studies of the flipped classroom method in medical education are small and observational, there is growing consensus that students favor this method over the traditional lecture.[15,31-35]

Proponents of this flipped classroom model hypothesize that it allows adult learners to integrate new knowledge with existing knowledge.[9-10] The act of covering material independently at their own pace prior to a meeting promotes deeper learning, longer retention and life-long learning skills. The face-to-face classroom sessions promote knowledge application, critical thinking, creativity, and peer-faculty interactions.

Additionally, the flipped classroom may prepare learners for eventual information-gathering and decision-making in complex clinical settings by mimicking real-life interprofessional interactions.[13-14] Conversely, challenges associated with the flipped classroom model include perceived time commitment for both educators and learners, effective integration of technology, ensuring individual learner accountability, and promotion of a safe learning environment.[29,31,34,36]

Problem Statement

Medical education continues to shift from traditional, lecture-based teaching to approaches that promote higher-order thinking and active learning.[1] The flipped classroom instructional method is rapidly increasing in popularity amongst graduate medical education training programs as a preferred method to educate adult learners using active and social learning theories. Literature on the flipped classroom has proliferated rapidly across health sciences education; however, a recent systematic review yielded very few articles on the effectiveness of this educational method within the graduate medical education setting. While the literature is rather convincing that students prefer the flipped classroom pedagogical approach to traditional lecture-based instruction, there continues to be a paucity of meaningful data detailing the effectiveness of this educational approach using specific educational outcomes. Given the overall lack of meaningful data on the effectiveness of the flipped classroom educational method in graduate medical education, this study aims to remedy the perceived gap in the medical education literature detailing the effectiveness of this pedagogical approach to this population of adult learner.

Purpose

The Accreditation Council for Graduate Medical Education (ACGME) requires that emergency medicine residency programs provide an average of at least five hours of weekly didactic instruction that is to include problem-based learning (PBL), evidence-based medicine (EBM), or computer-based instruction.[37] Resident physician learners are required to participate in at least 70% of these didactic sessions. Historically, The Ohio State University Emergency Medicine residency program has fulfilled the ACGME didactic requirement through weekly lectures. For the 2015-2016 academic year, the program changed the didactic format to a flipped classroom model.

The primary purpose of this study is to evaluate the outcomes of the first year of flipped classroom instruction, and compare it to preceding years of lecture instruction. An additional aim of this study is to critically evaluate the breadth and quality of the medical education literature pertaining to the flipped classroom instructional method in graduate medical education programs. The final purpose of the study is to assess learner satisfaction with the implemented flipped classroom pedagogical approach. This cross-sectional cohort study will contribute to the relative paucity of data on the effectiveness of the flipped classroom instructional method in a graduate medical education training program.

Theoretical Framework

Andragogy, the theoretical framework consisting of the art and science of adult learning, makes five key assumptions about the adult learner. Adult learners are self-directed and continually develop and draw from a reservoir of prior knowledge and

experience. They are eager to learn as it pertains to their development and social or professional roles. Finally, they have an internal motivation to learn, and their learning is problem-centered.[11] Andragogy is also based on four principles applied to adult learning. Adults need to participate in the planning and evaluation of their learning, and are most interested in learning subjects that are directly relevant to their profession or personal life. In andragogy, experience provides the foundation for learning, and adult learning is problem-centered rather than content-oriented.[11]

The successful implementation of a flipped classroom pedagogical approach relies heavily on the theoretical framework of andragogy. Learners are expected to be internally motivated and self-directed when both choosing educational materials and learning the content in preparation for classroom application. Additionally, classroom time is problem-centered and aimed at application of the material learned independently. This design allows educators and learners to achieve higher-level learning on Bloom's Taxonomy theoretical framework.[10]

Research Questions

The entirety of this research study aims to address several different research questions. First, what is the breadth and quality of existing literature on the use of the flipped classroom pedagogical approach in graduate medical education? This question will be thoroughly addressed by a systematic review and evaluation of the existing literature. Second, within a large academic emergency medicine residency program, what was the learner satisfaction and perception of effectiveness of the implemented flipped classroom didactics? This question is addressed using a program evaluation survey

delivered to each individual learner that experienced the change in instructional method. Finally, the primary question addressed by this research study is the overall effectiveness of the flipped classroom instructional method in a graduate medical education program. Using the American Board of Emergency Medicine in-training examination as an outcome measure, is the flipped classroom pedagogical approach superior to lecture-based instruction in graduate medical education? This question is addressed using a cross-sectional cohort study design.

Methodology

A systematic literature search of the major health and social science databases was performed. Articles were screened to ensure they described use of the flipped classroom method in an ACGME accredited residency program and included research outcomes. Resulting articles were analyzed, described and evaluated for research quality using the Kirkpatrick Framework and the Medical Education Research Study Quality Instrument (MERSQI).

During the 2015-16 academic year, The Ohio State University Department of Emergency Medicine structured the residency conference day around themes covering patient presentation or chief-complaint (eg. chest pain, pregnancy, shortness of breath). Lectures were replaced with facilitated small group discussions using the flipped classroom model and case-based learning. Departmental educators also incorporated simulations and procedure sessions into the conference day. Residents prepared for conference by reviewing related patient cases, identifying and selecting learning materials, and then reviewing those materials. Residents were provided with

recommended learning materials, but were also encouraged to identify and select their own to best fit their individual learning needs. Conference time was reserved for facilitated small group discussions about the cases and residents were given the opportunity to apply what they learned from the associated reading material to diagnose and develop management plans for the patient cases.

The author performed a cross-sectional cohort study of emergency medicine residents who entered the emergency medicine residency program between 2011 and 2016. The average enrollment grew over this time frame n=12 per entering class to n=18. All emergency medicine residents at this institution within the study timeframe were included within the study. The author compared the performance of those residents who participated in the flipped classroom to those who received the lecture curriculum on the annual American Board of Emergency Medicine (ABEM) in-training examination, (a 225-question standardized test lasting 4.5-hours and normed to all residents in the U.S. ACGME-accredited emergency medicine residency programs). Additionally, the author developed a program evaluation questionnaire to assess resident opinions of their educational experiences. The questionnaire simply asked residents to rate each component of the residency program on the quality of instruction and the value to their professional development. Response options for quality included 1=Poor, 2=Marginal, 3=Satisfactory, 4=Good, and 5=Excellent. The response options for value included 0=No value, 1= Minimal value, 2= Moderate value, 3= Considerable value, and 4= Great value. Residents were also asked how much time they spent (in hours) with three types of learning materials: textbooks, online-instruction, and journals.

The author used paired comparisons (independent t-tests to compare exam scores for residents who experienced the lecture-based curriculum to those of residents in the new flipped classroom curriculum), while controlling for program level of training (i.e., interns from the new curriculum were compared to interns in the old curriculum, etc.).

Definition of Terms

Flipped Classroom: An instructional strategy and a type of blended learning that aims to increase student engagement and learning by having students study materials independently, while working on live problem-solving in the classroom.

Andragogy: The methods and principles used in adult education.

Pedagogy: The approach to teaching and the theory and practice of learning.

PGY1: Medical resident in first post-graduate level of training.

PGY2: Medical resident in second post-graduate level of training.

PGY3: Medical resident in third post-graduate level of training.

Significance

Medical education continues to evolve at a rapid pace in conjunction with new innovations and further developments in adult learning theory. Current, prevailing andragogical theory promotes the use of active learning methods to maximize adult learning. The flipped classroom instructional method utilizes an active learning framework to promote higher order learning. While theoretically sound and preferred by learners in graduate medical education, there is a paucity of meaningful data detailing the effectiveness of this pedagogical approach in the graduate medical education setting using defined, measurable educational outcomes. While limited to a single residency

training program at a single institution, this research study will be beneficial to both institutions and medical educators involved in training resident physicians worldwide. This study will enhance the paucity of literature on the effectiveness of this educational approach in the graduate medical education setting by adding Kirkpatrick level two and three outcome data to the existing literature.

Assumptions, Limitations, and Delimitations

Throughout this particular research study, several assumptions were made to ensure that the study could be adequately and ethically conducted. First, this study assumes that the resident learners at this large academic emergency medicine residency program were self-directed, motivated adult learners that would actively learn the material and participate in small group discussions despite not receiving detailed assessments of their performance. Second, in accordance with andragogical theory, this study assumed that learners would have a plethora of life experiences to serve as a scaffold for new knowledge. Finally, to ensure the ethical instruction of the resident learners, this study assumed that the flipped classroom pedagogical approach would be equally effective as compared to standard lectures in educating resident learners.

This research effort suffers a few limitations, the worst of which was incomplete program evaluation data from the residents, particularly in the second year of the study. While the study reached nearly a 40% return rate from residents in that academic year, the probability of selection bias was high. The author checked for selection bias and recognize that the respondents represented more PGY-1 and 3 residents.

While the American Board of Emergency Medicine in-training examination tests the collective medical knowledge of resident trainees, this single, annual assessment of medical knowledge may not be sufficiently sensitive to detect the subtle differences in educational achievement obtained from two different curriculum models. While the flipped classroom method of teaching is designed for deeper learning and longer-term retention, an annual standardized test may not be the best measure of this type of learning.

Future studies using assessment instruments more specifically designed for measuring educational efficacy between the flipped classroom model and traditional lecture methods are needed. Furthermore, study designs that are effective at isolating the type of learning that occurs in classroom didactics from the type of learning that takes place in the clinical environment could contribute to further understanding the efficacy of different curriculum methods.

Study Organization

Ultimately, this study aims to address multiple research questions that resulted in the inception of this medical education research study. First, a systematic review of the medical education literature will profile both the use of and assess the quality of the research literature on the flipped classroom specifically used in graduate medical education. Furthermore, this study aims to determine if the flipped classroom pedagogical approach is more effective than the traditional, lecture-based method of instruction in our population of emergency medicine resident learners. In order to answer this specific research question, multiple different types of data from both instructional methods are

analyzed. Important data includes the comparison of the American Board of Emergency Medicine annual in-training examination scores to identify potential differences in knowledge retention among the different instructional methods, and a residency program evaluation questionnaire to assess resident opinions of their educational experiences. The methodology and results of the study are presented in detail, followed by a detailed discussion on the results obtained from the study. The study will conclude with a discussion of the major conclusions derived from the study, in addition to necessary future directions for further study.

Chapter 2. Systematic Literature Review

Compared to the undergraduate medical education setting, the implementation of the flipped classroom pedagogical approach in the graduate medical education setting is more challenging. Resident learners may be less motivated by grades and are more motivated by learning that directly helps them with patient care.[8] Additionally, the graduate medical education learner's primary role is care provider, while the undergraduate medical education learner's primary role is student. Given the marked differences in learning environments between undergraduate and graduate medical education settings, and the flipped classroom's increasing popularity with residency programs;[19] a review specific to the effectiveness of the flipped classroom method in graduate medical education was needed. The goal of this systematic review is to profile the use of and assess the quality of the research literature on flipped classroom methods used throughout graduate medical education programs.

This systematic review of the literature conforms to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for systematic reviews and was performed in accordance with best practice guidelines.[38] The author of this study, in conjunction with a health sciences librarian, performed comprehensive searches of multiple databases, including PubMed, CINAHL Plus, Embase, Web of Science Core Collection, and ERIC on July 27, 2018. Search alerts were used to gather new records

through July 27, 2019. Major search terms and strategies are provided in appendix A. To identify additional manuscripts, the author also searched MedEdPORTAL and reviewed bibliographies of included studies.

Inclusion and Exclusion Criteria

All articles published through July 2019 involving the use of flipped classroom in ACGME accredited residency programs were screened. Articles that pertained to residents in any year of training from any medical specialty were included. Other inclusion criteria involved full-text articles that had undergone peer review and described some form of research or evaluation. Articles that involved flipped classroom instruction with learners in non-medical education settings and at other levels of medical education, including undergraduate medical education, fellowship, or continuing medical education were excluded. Published abstracts were also excluded from consideration. The author chose to err on the more inclusive side by including articles that involved research or evaluation about pre-classroom learning activities associated with flipped classroom instruction. Pre-classroom learning activities are designed to introduce new knowledge to prepare the learners for the classroom session where they will apply the mew knowledge from pre-session activities.

The author initially screened titles and abstracts of retrieved articles, and subsequently selected articles for full-text review. The author then reviewed the full-text articles and made the determination for inclusion in the final quality review.

Data Extraction

The author extracted the following variables for each study: authors, publication year, medical specialty, level of trainees, education topic, flipped classroom method, specific intervention, number of flipped classroom participants, study design, and study outcomes. Research design terms used for classifying study design were derived from Campbell and Stanley.[39]

Quality Assessment

The systematic review of the literature used the modified Kirkpatrick framework to classify study outcomes of educational intervention according to impact level.[40] The modified Kirkpatrick classification levels are summarized here:

1 = measures of learner perceptions;

2a = self-reported changes in learner opinions

2b = changes in knowledge or skills

3 = changes in learner behavior

4a = change in professional practice

4b = change in patient's condition

When not provided, the author attempted to extract information needed to calculate associated Cohen's d effect sizes for each outcome.[41-42]

Finally, the systematic review used the Medical Education Research Study Quality Instrument (MERSQI) to assess the quality of selected studies.[43-44] This 10-item scale provides a measure of methodological quality across six domains: study design, sampling, type of data, validity, evidence, data analysis, and outcomes. Total MERSQI

scores range from 2 (low quality research) to 18 (high quality research). The author independently scored each article.

Search Strategy

Figure 1 illustrates the systematic review process. The initial search yielded 2562 articles. After removing duplicates, 2123 studies were screened using titles and abstracts. Articles were excluded based on criteria outlined earlier, which resulted in 116 articles for full-text review. Of these 116, an additional 94 were excluded because they did not meet the selection criteria. The final list of articles that met criteria for quality review included 22 articles.[8,33,35,44-63]

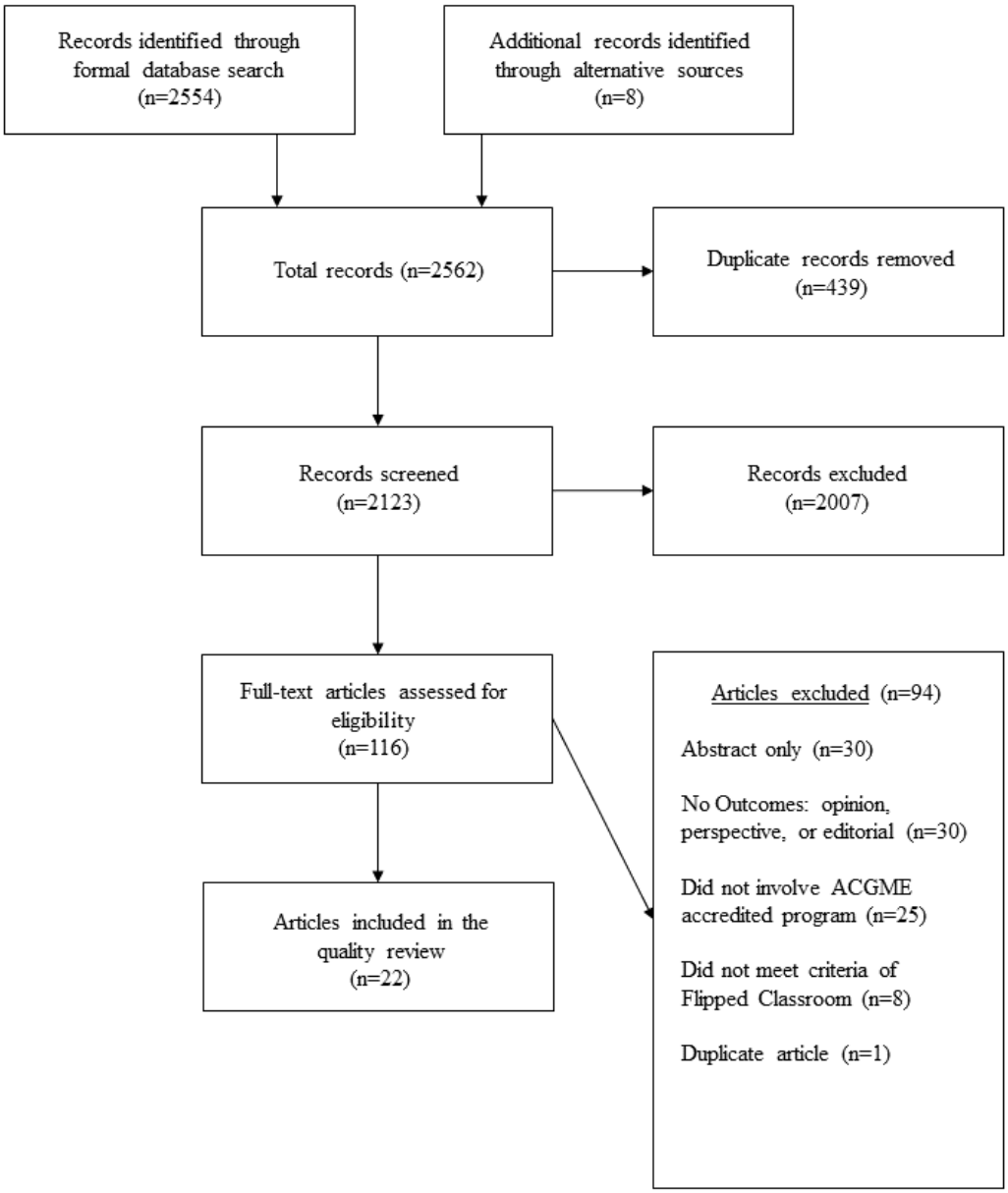

Figure 1: PRISMA Diagram illustrating the selection and review process of articles related to the "flipped classroom" in graduate medical education in the United States

Education Content

The 22 studies included in the final analysis are presented in Tables 1 and 2. All were published in the past five years (2014-2018), most (86%) in the past three. Across all studies, about 985 learners were involved with a flipped classroom intervention. Thirteen medical specialties were represented including: anesthesiology,[53,56-57,63] emergency medicine,[8,33,35,45,51] internal medicine,[46] internal medicine-pediatrics,[50] neurology,[54] neurosurgery,[48] obstetrics and gynecology,[61-62] pathology,[49] pediatrics,[47,50,58] psychiatry,[52] radiology,[59] thoracic surgery,[55] and surgical intensive care.[60] All study designs were quantitative; however, a few gathered feedback through open-ended survey items.

First Author	Year Published	Level of Participants	Specialty	Topic	Type of Flipped Classroom	How Flipped Classroom Implemented
Barrie[45]	2018	PGY1	Emergency Medicine	Core medical knowledge for Level 1 Milestone (MK)	Traditional Small Group	Used FC to replace lectures during intern orientation
Bonnes[46]	2017	PGY1-3	Internal Medicine	Quality Improvement	Project-based learning with Traditional Flipped Classroom	Used FC to replace lectures during a 1-month rotation
Chokshi[47]	2017	PGY2	Pediatrics	Resident as Teacher	Team-based Learning	Use of FC for four 1-hour workshops delivered in one day

Continued

Table 1: Flipped Classroom Methodology in Graduate Medical Education

Table 1 Continued

First Author	Year Published	Level of Participants	Specialty	Topic	Type of Flipped Classroom	How Flipped Classroom Implemented
Girgis[48]	2018	PGY1-7	Neurosurgery	Core neurosurgical topics	Just-in-time Learning	Used FC with assigned questions by level of training to replace lectures for entire didactic curriculum
Haspel[49]	2016	PGY1-3	Pathology	Molecular genomic pathology; Next generation genomic sequencing	Team-based learning	FC with TBL used with a four part workshop on molecular genomics delivered at pathology conferences
Keefer[50]	2016	PGY1	Pediatrics and Combined Internal Medicine and Pediatrics	Quality-Improvement	Project-based learning with Traditional FC	Used FC for a 4-session quality improvement curriculum
King[51]	2018	PGY1-3	Emergency Medicine	Core curriculum content for EM residency	Traditional Small Group FC	Used FC to replace lectures for entire didactic curriculum
*Lockhart[52]	2017	PGY2	Psychiatry	Neuroscience of schizophrenia	Traditional Small Group FC	Use of a Small-Private Online Course to prepare conference attendees for a FC experience

Continued

Table 1 Continued

First Author	Year Published	Level of Participants	Specialty	Topic	Type of Flipped Classroom	How Flipped Classroom Implemented
Martinelli[53]	2017	PGY2	Anesthesia	Pharmacology portion of the Anesthesia Board Content Outline	Traditional Small Group FC with case discussions and audience response system questions	Study comparing FC to lecture for 4-consecutive weekly sessions across 8 residency programs
*Moeller[54]	2017	PGY2-4	Neurology	EEG sub-competencies from the ACGME milestones	FC with EEG interpretation sessions	Evaluation of video-based lectures during 1-month Clinical Neurology rotation
Mokadam[55]	2016	All Levels	Thoracic Surgery	Core Thoracic Surgery Curriculum	Case-based Learning	Used FC and weekly quizzes to replace lectures for entire didactic curriculum
Olsen[56]	2018	PGY1-2	Anesthesia	Essential skills for beginning residents in anesthesiology	Preparation work followed by 3-day simulation boot camp	Assigned pre-session instructional videos as part of an intern boot camp for teaching ACLS skills
*Ortega[50]	2016	All Levels	Anesthesia	Core Anesthesia Curriculum-Fundamentals	Problem-based and case-based discussions	Adoption of an interactive multi-media enhanced textbook with FC to replace weekly lectures

Continued

Table 1 Continued

First Author	Year Published	Level of Participants	Specialty	Topic	Type of Flipped Classroom	How Flipped Classroom Implemented
Peterson[58]	2017	PGY1	Pediatrics	How to apply clinical guidelines	"Modified" FC in which content knowledge material is read in class	Pilot study of three 30-minute modified FC sessions on clinical practice guidelines
Riddell[8]	2017	PGY1-4	Emergency Medicine	Acute low back pain & acute headache	Traditional Small Group FC	Cross-over study comparing FC to lecture for two topics
*Rose[35]	2016	PGY3	Emergency Medicine	Advanced pediatric life support topics.	Preparation materials followed by simulations and procedures lab	Assigned pre-course video lectures to prepare residents for PEM simulation and procedures boot camp
Sajedi[59]	2018	PGY1	Radiology	Preparing interns for overnight call	Traditional Small Group FC with in-class activities dedicated to correcting knowledge gaps observed in pretest	Used FC to replace noon conference lectures
Tainter[60]	2016	PGY2-4	Resident Rotators in Surgical Intensive Care Unit	Point-of-care echocardiography	Preparation materials followed by interactive practice sessions	Used FC on SICU rotation over four sessions

Continued

Table 1 Continued

First Author	Year Published	Level of Participants	Specialty	Topic	Type of Flipped Classroom	How Flipped Classroom Implemented
Urban[61]	2014	PGY1-4	Obstetrics and Gynecology	Core gynecology -oncology curriculum	Traditional Small Group FC with identified learning points incorporated into case discussions on rounds	Used FC to replace lectures on gyn-onc rotation (One hour per week for 8 weeks)
Valente[62]	2018	PGY1-2	Obstetrics and Gynecology	Core content for the OB/GYN in-training examination.	Modified Team-Based Learning without the group assessment test	Used FC to replace lectures for entire didactic curriculum
*Vasipoulos[63]	2015	Residents and Medical Students	Anesthesia	EEG interpretation	Flipped instruction involving self-study using podcasts followed by guided instruction	Evaluation of podcasting as a tool, which while not specified, used an FC model of instruction
Young[33]	2014	PGY1-3	Emergency Medicine	Syncope, Pediatric presentations	Traditional Small Group FC	Pilot study of two FC sessions offered during didactic schedule

* Dark shading indicates studies that focus predominantly on pre-class methods rather than the FC method.

Authors of these studies offered numerous reasons for incorporating the flipped classroom into their residency programs. Some suggested that using the flipped classroom was a solution to scheduling issues; either saving time in already saturated didactic schedules, or providing schedule flexibility.[35,45-46,48,55,59,62] Others suggested that

the flipped classroom method was selected to improve didactic instruction, motivate or engage learners, promote active learning, or prepare for more advanced levels of content material.[45-49,51,53-54,56,60]

Residency programs adopted the flipped classroom method in one of three ways. Most commonly, authors described "occasional" use of the flipped classroom for a single lesson; usually to emphasize an important topic such as: quality improvement;[46,50] resident-as-teacher skills;[47] using clinical guidelines;[58] echocardiography (ECG) or electro-encephalograph (EEG) interpretation;[54,60,63] or pediatric advanced life-support (PALS).[35] Other programs have replaced their entire didactic curriculum with FC sessions.[48,51,55,57,61] Three articles describe the use of the flipped classroom pedagogical approach for portions of their didactic curriculum: intern orientation;[45,56,59] to reinforce important basic science principles;[49,52-53] and weekly didactics during one or two month rotations.[46,54,60-61] As proof-of-concept projects, Haspel and Lockhart designed flipped classroom instruction for delivery at national conferences.[49,52]

Concerns about the flipped classroom surfaced in some of the literature reviewed, particularly around learner compliance with self-directed learning. The study by Rose discovered that residents did not accurately report time spent on viewing video lectures in preparation for FC activities.[35] Residents in the Young study suggested that time for pre-class preparation was a weakness of the FC format.[33] Without adequate pre-class preparation, learners are unable to effectively participate in applying content knowledge during the in-class meeting. Consequently, several studies involved the production of innovative methods for delivering pre-class content such as podcast lectures, interactive

electronic modules, or multi-media textbooks. These materials were designed specifically to cajole learners into completing the self-directed learning required for constructive participation during in-class activities.[35,48,52,54,56-57,63]

Study Outcomes

Five of the selected articles focused more on pre-class methods and less about the flipped classroom instruction method itself. Lockhart assessed the implementation of a small, private, on-line course (SPOC).[52] Moeller and Vasilopoulos studied the effectiveness of podcast lectures.[54,63] Rose studied the impact of embedding multiple choice questions into instructional videos,[35] while Ortega evaluated a multi-media, interactive textbook.[57] Since none of these studies reported outcomes related to both pre-class and in-class flipped classroom methods, they were not subjected to Kirkpatrick classification.

Level 1 Outcomes-Perception. Most of the seven studies that evaluated Level 1 outcomes were not designed for control group comparisons, or change over time.[48-51,55,58,62] Accordingly, effect sizes were not appropriate for Level 1 articles. The exception was the article by King who compared ratings of components of the curriculum before and after the program switched from lecture-based to flipped classroom methods. Residents rated all components higher under the flipped classroom model, but only two (adult and pediatric case conferences) were deemed significantly higher in quality and value which yielded large effect sizes d=1.19 and 1.10 respectively.[51]

Level 2a Outcomes-Change in opinion. Seven of the articles reported changes in learner opinions about the flipped classroom, the content taught, or the learners

themselves.[45-47,50,53,56,59-60] Changes in opinion about the FC method were observed in a control group study and a pre-post study, both yielding large effect sizes of 1.1 and .95 respectively.[46,53] Residents improved their opinion about teaching in a pre-post study of resident-as-teacher skills, which also yielded a large effect (.95).[47] Studies that reported changes in self-efficacy, confidence, comfort, or anxiety yielded smaller effect sizes ranging from .32-.84.[46,56] The exception involved the Bonnes resident-as-teacher study which generated a large 1.68 effect size for change in self-assessment of resident teaching skills.[46] Effect sizes could not be calculated for the remaining articles reporting level 2a outcomes.[45,50,59-60]

Level 2b Outcomes- Change in knowledge or skills. A third of the articles reported changes in knowledge or skills that came from controlled studies involving either parallel or historic control groups.[8,46,48,51,53,58,61-62] Effect sizes for these studies ranged from large (1.56) to negative (-0.51). An additional five articles reported changes in knowledge or skills that came from pre-posttest studies, two of which had associated effect size that were either large (.81)[47] or very large (2.73).[45] Effect sizes could not be calculated for the other three articles.[50,59-60]

Level 3-Outcomes-Change in Behaviors. Only two studies reported changes in behaviors, one involving increases in self-directed learning outside of class,[51] and one reporting inflated, self-reported, pre-class preparation times when compared to actual preparation times.[35] The effect size for the first was large (.85).[51] The effect size for the second could not be calculated.[35]

Study Quality

Cook provides a table of normative data for interpreting MERSQI scores. A mean score of 10 (Range: 5-16) was generated through a review of 210 articles covering medical education.[43] For the specific topic of residency education, the mean MERSQI of 12.9 (Range: 9-15.6) was generated through a review of 97 articles. This is considerably higher than the mean MERSQI score of 10.9 observed for the 22 articles reviewed (Range: 4-15.5, Std. Dev.=3.08). By dropping four pilot or proof-of-concept studies which had only Level 1 outcomes from the analysis,[33,52,54,57] the average MERSQI score would be more comparable to the normative data reported by Cook (Mean=12.08, Range=8.5-15.5, Std. Dev=1.93).

A look across individual MERSQI items suggests that the research on the flipped classroom in GME is still in its infancy. The literature review included numerous articles that were considered pilot or proof-of-concept studies. Some specifically targeted investigations of the development of content delivery methods for pre-class preparation such as video lectures,[50,53] podcasts,[48,58] or in one case a multi-media interactive textbook.[51] Only half of the articles reviewed used experimental or quasi-experimental designs with control groups (either a control arm or historical controls).[8,46,48,51,53,55-56,58,61-62] The other half were pre-experimental: involving only one group pre-posttest or posttest-only designs.[33,35,45,47,49-50,52,54,56,59-60,63] Only five studies involved cross-institutional collaborations.[8,45-46,53-54] While almost three quarters used objective measures, very few articles provided validity evidence in the form of construct, or content validity. Furthermore, articles investigating the relationship between relevant

variables were limited. On the positive side however, more than three-quarters (77%) of the studies used appropriate analyses and almost 70% implemented inferential statistics to analyze outcome variables such as knowledge or skills.

First Author	Study Design	Kirkpatrick Levels & Study Outcomes with associated effect sizes*	MERSQI Score
Barrie[45]	One-group pretest-posttest design (n=12)	2a. Participants felt more proficient with the core content of the curriculum. [d=NA] 2b. 1. Average gains on comprehensive knowledge test of 12.6 percentage points from pre-to-posttest [d=2.73; (1.6, 3.8)].	12.5
Bonnes[46]	Pretest-posttest control group design (FC=95, Control=48)	2a. Residents in FC showed significant increase in preference for it compared to control. [d=1.1;(.5, 1.7)] 2a. Perception about online learning modules, in-class projects, and working in teams increased significantly. [d=.35; (-.15,.85)] [d=.32; (-.18, .81)] [d=.32; (-.18, .82)] 2b. Knowledge scores on QIKAT were significantly better for FC group compared to control group. [d=1.02; (.5, 1.5)].	13.5

Continued

Table 2: Summary of Study Outcomes and Analysis

Table 2 Continued

First Author	Study Design	Kirkpatrick Levels & Study Outcomes with associated effect sizes*	MERSQI Score
Chokshi[47]	One-group pretest-posttest design (n=29)	2a. Residents showed improved attitudes towards teaching after the training session. [d=.95; (.40, 1.49)] 2a. Residents rated themselves as more effective teachers after the session. [d=1.68; (1.2, 2.28)] 2b. Participants performed significantly better on an Observed Structured Teaching Examinations (OSTEs). Teaching a skill [d=1.10; (.5, 1.7)] Giving feedback [d=.81;(.2, 1.4)] Orienting a learner [d=1.06;([.4, 1.7)]	13
Girgis[48]	Static group comparison (n=12)	1. Participants expressed a preference for the FC. [d=NA] 2b. Performance on board examination improved significantly. [d=1.56; (.6, 2.40]	11
Haspel[49]	Post evaluation survey only (n=62)	1. Participants evaluated positively. [d=NA]	8.5
Keefer[50]	One-group pretest-posttest design (n=54)	1. Participants were more comfortable about QI projects. [d=NA] 2b. Scores on tests were higher on posttest than on pretest. [d=NA]	9

Continued

Table 2 Continued

First Author	Study Design	Kirkpatrick Levels & Study Outcomes with associated effect sizes*	MERSQI Score
King[51]	Static group comparison (FC=101, Control=86)	1. Residents in FC rated most components of new curriculum higher in value and quality than those in lecture. Two components were considered significantly higher in quality. [d=1.19; (.56, 1.83)] [d=1.10; (.47, 1.7)] 2b. Scores on in-training exams were comparable between lecture and FC curriculum. [d= .12;(-.4, .6)] [d= -.5; (-1.0, 0)] [d= -.51;(-1.0, 0)] 3. Residents devoted more time to independent study in FC curriculum. [d=.85; (.22, 1.45)]	12
Lockhart[52]	Proof-of Concept: Post evaluation survey only (n=24)	Participants evaluated the instructional format of the small private on-line course positively. [d=NA]	4
Martinelli[53]	Pretest-posttest control group design with 4-month follow up (FC=81, Control=56)	2a. FC participant's preference for the FC significantly improved pre-post. [d=.95; (.47, 1.4)] 2b. FC approach resulted in higher levels of long term knowledge retention after 4 months. [d=.56; (.2, .9)]	15.5

Continued

Table 2 Continued

First Author	Study Design	Kirkpatrick Levels & Study Outcomes with associated effect sizes*	MERSQI Score
Moeller[54]	Pilot study: Post evaluation survey only (n=15)	Participants evaluated the video-based lectures positively as prep for FC [d=NA].	7
Mokadam[55]	Time-series control group design (FC=10, Control=NR)	1. Participants evaluated the FC experience positively compared to lecture. [d=NA] 2b. Change in participant scores on knowledge tests change over time at a higher rate than those of faculty [d=NA] 3. Reading of content material increased significantly in FC model. [d=NA]	12
Olsen[56]	Static group comparison using self-efficacy measure (FC=17, Control=10)	2a. Participants self-efficacy increased after implementing FC with simulation boot camp. Procedures [d=.77; (.10, 1.4)] Autonomy [d=.89; (.20, 1.6)] Overall [d=.84; (.16, 1.5)]	9
Ortega[50]	Post evaluation survey only (n=25)	Participants evaluated the interactive textbook positively as prep for FC [d=NA].	6

Continued

Table 2 Continued

First Author	Study Design	Kirkpatrick Levels & Study Outcomes with associated effect sizes*	MERSQI Score
Peterson[58]	Pilot study: Pretest-posttest control group design (FC=10, Control=19)	1. Participants in the FC rated the experience positively. [d=NA] 2b. Residents in the FC performed better on all 3 knowledge test topics as compared to control. Obstructive sleep apnea [d=.93; (.09, 1.8)] Acute otitis media [d=1.10; (.28, 1.9)] ADHD [d=1.10; (.28, 1.9)]	12
Riddell[8]	Cross-over design with pre, post, and follow-up tests (FC=37, Control=36)	2b. No difference in knowledge scores over two topics were observed between FC and control groups. Low back pain [d=.02; (-.3, .4)] Headache [d=.32; (-.7, 1.4)]	15.5
Rose[35]	One-group pretest-posttest design-with group split across two methods of pre-class preparation (Intervention=17, Control=17)	Residents who received questions imbedded into pre-FC didactic video lectures showed significant improvement in scores compared to those who did not. [d=NA] Residents preferred online lectures to live lectures and the inclusion of questions in online lectures. [d=NA] Participants did not accurately report their online viewing behaviors. [d=NA]	12

Continued

Table 2 Continued

First Author	Study Design	Kirkpatrick Levels & Study Outcomes with associated effect sizes*	MERSQI Score
Sajedi[59]	One-group pretest-posttest design (n=12)	2a. Participants reported reduced anxiety and increased comfort levels about call cases after FC intervention. [d=NA] 2b. Participants scores on knowledge tests went up after FC intervention. [d=NA]	11
Tainter[60]	One-group pretest-posttest design (n=39)	2a. Ratings of confidence in and likelihood of using ultrasound increased significantly. [d=NA] 2b. Post intervention scores of knowledge significantly improved on all 4 modules. [d=NA]	12
Urban[61]	Static group comparison (FC=30, Control=259)	2b. Scores on in-service examination subtest covering content taught with FC increased 6.5% over same content taught by lecture during years prior. [d=.64; (.3, 1.0)]	13.5
Valente[62]	Static group comparison (FC=10, Control=15)	2b. No significant differences on in-training exam were observed between FC and traditional cohorts after controlling for USMLE scores. [d=NA]	12.5

Continued

Table 2 Continued

First Author	Study Design	Kirkpatrick Levels & Study Outcomes with associated effect sizes*	MERSQI Score
Vasipoulos[63]	One-group pretest-posttest design-with group split by levels of pod-cast experience. (Intervention=33, Control=24)	Residents who completed podcasts prior to guided-instruction did better than residents who did traditional didactic instruction prior to guided-instruction. [d=.35; (-.2, .9)] Those who had more experience with podcasts performed significantly better than those who had less experience. [d=NA]	13
Young[33]	Pilot study: Post evaluation survey only (n=35)	Participants preferred online video lectures over live lectures and the majority stated a preference for FC on a monthly basis. [d=NA] 1. Participants offered more advantages for using the FC than they did disadvantages. [d=NA]	6

*Cohen's d effect size. Effect sizes can be interpreted as follows: $\leq$ .20 is considered "no effect;" .21-.50 is considered a "small effect;" .51-.70 is considered an "intermediate effect;" $\geq$ .71 is considered a "large effect."(see Lenhard & Lenhard). Abbreviations: NA= Effect size calculation not possible due to study design or insufficient information.

Dark shading indicates studies that focus predominantly on pre-class methods rather than the FC method.

Discussion of the Systematic Review of the Literature

This systematic review of the application of flipped classroom in GME yielded several important findings. While still in its early stages, research on the flipped

classroom method in GME has increased substantially over the past five years, with 17 of 22 articles being published since 2016. Additionally, the author discovered use of the flipped classroom approach in at least thirteen types of residencies suggesting that the teaching method can be broadly adopted across a variety of GME settings. Purposes for use of the flipped classroom and specific techniques on how it was applied vary greatly across programs, suggesting that it is not a one-method-fits-all intervention. The author found that the flipped classroom has been applied to entire residencies or on a more limited scale within rotations or to cover specific topics. The method has also been used across institutions to prepare learners for specialized topics, or to capitalize on educator expertise.

The author attributes the rise of interest in the flipped classroom in GME to medical educator's desire to find something better, recognition that this method is suitable for residents, and can be adapted to the GME setting. The self-directed learning component gives residents more control over their learning, allowing them to learn content at their own pace and during times outside of their clinical responsibilities. Consistent with social learning theory, the flipped classroom provides a venue for collaborative learning where adults publicly demonstrate their application of knowledge during small group discussion of patient cases and problems.[7-8] Further, learner enthusiasm for the flipped classroom method and documented improvements in knowledge and skills make the flipped classroom an attractive alternative to the traditional lecture-based education model.

Medical educators within the literature suggest that their interest in the flipped classroom is associated with making more effective use of instructional time, providing more structure for self-directed learning outside of class, or motivating residents to spend more of their time outside of clinical responsibilities engaged in study. One of the weaknesses of the flipped classroom involves learner completion of the self-directed learning activities required for constructive participation during in-class sessions. Since their learners have clinical responsibilities that compete for their time, this was of concern among graduate medical educators. The author believes the number of studies involving production of more interesting methods for delivering pre-class content were directly related to this concern.

F. Chen's earlier systematic review on the topic of the flipped classroom approach in medical education found that the "majority of literature has been carried out in undergraduate medical education." Additionally, their review suggests that research up to that point "lacked strong evidence for the effectiveness of flipped classrooms."[3] A subsequent comprehensive meta-analysis by KS Chen covered a relatively small number of studies involving medical education and only one that involved residency education.[30] This group of authors tentatively suggested an advantage of the flipped classroom over lecture-based methods; however, they expressed concern about this interpretation due to extreme diversity in methods. This systematic review of the literature focused solely on the use of the flipped classroom in ACGME accredited residency programs. Like KS Chen, the author confronted diversity in research methods but also diversity in how the flipped classroom was applied and the content covered. In contrast with F. Chen, and

comparable to KS Chen, the author found that learners generally find the flipped classroom approach acceptable, and evidence supports that the flipped classroom is as good as the traditional didactic approach (introducing topics through lecture or during a face-to-face meeting followed by readings and study of educational materials).

This systematic review of the literature has some limitations. While the author employed a comprehensive search strategy with the help of an experienced medical librarian, it is possible that he did not include more esoteric terms that refer to methods associated with flipped classrooms. For example, the author did not use the term "problem-based learning," which is a method that typically describes a comprehensive approach to education, but on a more limited basis, could be associated with the flipped classroom format. In addition, the author made the decision to exclude non-ACGME residency programs, such as those found outside of the U.S., and U.S. fellowship programs. This decision was based on the variability of education structures found outside of the U.S. and variability in size and purpose of fellowships. These decisions may have restricted the generalizability of our findings.

The assessment of higher-level outcomes, such as changes in learner behaviors or patient outcomes, remains a challenge in medical education.[43] Higher-level outcomes are difficult to assess because they can rarely be attributed to a single educational intervention. Despite these challenges, the author was heartened to find an increasing number of studies that generated Kirkpatrick Levels 2a, 2b, and 3 outcomes; many studies that employed objective measures, and an increasing number of studies that employed more rigorous research designs. Future research on the flipped classroom in

GME should focus on higher-level outcomes such as changes in behaviors, clinical practice, and patient outcomes.[40]

Conclusions from the Systematic Review of the Literature

The flipped classroom pedagogical approach in graduate medical education has been implemented in a variety of ways and studied with a variety of methods, which has yielded variable results. Using MERSQI scores, studies evaluating the efficacy of the flipped classroom were somewhat less rigorous on average than typical medical education research studies; however, if pilot and proof-of-concept studies are eliminated, the average MERSQI score was comparable to that of other medical education research studies. The studies that evaluated resident satisfaction or efficacy concluded that residents held generally positive opinions about the flipped classroom pedagogical approach. For the studies that evaluated learning outcomes, results were mixed: slightly more than half of the studies using a control group for comparison found positive learning results. Future studies of flipped classroom in GME should include higher level outcomes (changes in knowledge, behaviors, or patient outcomes) and assessment of pre-classroom assignment completion.

The systematic review of the medical education literature shows that the flipped classroom instructional method has been implemented and studied to varying degrees in graduate medical education. While theoretically sound and preferred by learners in graduate medical education, there is a paucity of meaningful data detailing the effectiveness of this pedagogical approach in the graduate medical education setting using defined, measurable educational outcomes. While limited to a single residency

training program at a single institution, this research study will be beneficial to both institutions and medical educators involved in training resident physicians worldwide. This study will enhance the existing literature on the effectiveness of this educational approach in the graduate medical education setting by adding Kirkpatrick level two and three outcome data to the picture.

Chapter 3. Methods

The overall purpose of this section is to thoroughly describe the research methodology employed in this educational research study. This chapter begins by describing the instructional methods implemented to be studied within The Ohio State University Department of emergency medicine residency program. Next, the study population and research conceptual framework are presented. The chapter concludes with a thorough presentation of the instruments and data analysis methods used within this educational research design.

Instructional Methods

During the 2015-16 academic year, The Ohio State University Department of Emergency Medicine structured our residency conference day around themes covering patient presentation or chief-complaint (eg. chest pain, pregnancy, shortness of breath). Lectures were replaced with facilitated small group discussions using the flipped classroom model and case-based learning. Departmental educators also incorporated simulations and procedure sessions into the conference day. Residents prepared for conference by reviewing related patient cases, identifying and selecting learning materials, and then reviewing those materials. Residents were provided with recommended learning materials, but were also encouraged to identify and select their

own to best fit their individual learning needs. Conference time was reserved for facilitated small group discussions about the cases and residents were given the opportunity to apply what they learned from the associated reading material to diagnose and develop management plans for the patient cases.

Research Questions

The entirety of this research study aims to address several different research questions. First, within The Ohio State University emergency medicine residency program, what was the learner satisfaction and perception of effectiveness of the implemented flipped classroom didactics? This question is addressed using a program evaluation survey delivered to each individual learner that experienced the change in instructional method. Ultimately, the primary question addressed by this research study is the overall effectiveness of the flipped classroom instructional method in a graduate medical education program. Using the American Board of Emergency Medicine in-training examination as an outcome measure, is the flipped classroom pedagogical approach superior to lecture-based instruction in graduate medical education? This question is addressed using a cross-sectional cohort study design.

Population

The author performed a retrospective cross-sectional cohort study of emergency medicine residents who entered the emergency medicine residency program between 2011 and 2016. The average enrollment grew over this time frame n=12 per entering class to n=18. The E-2011 and E-2012 cohorts (n=28) were the last two classes to experience only the lecture-based curriculum. The E-2013 and E-2014 cohorts

experienced both the lecture-based and flipped classroom curricula (n=31). The E-2015 and E-2016 cohorts experienced only the flipped classroom curriculum (n=36). All emergency medicine residents at this institution within the study timeframe were included within the study. Of the 95 residents involved in the study, 50 were male and 45 were female. Additionally, residents completed their medical education at a wide variety of medical institutions across the United States of America.

Research Design

As mentioned previously, this educational research study utilizes a cross-sectional cohort methodological design. The cross-sectional cohort design involves cross-sectional sampling to obtain a study cohort, and then retrospective assessment of outcomes in members of the cohorts over a defined period of time. The study cohort involves the set of individuals who are available for evaluation at a specific time point.[64] This research design was chosen because data utilized for this study was retrospective and involved several different cohorts that needed comparisons in order to most accurately assess the effect of the implementation of the flipped classroom method of instruction.

Instruments

The author compared the performance of those residents who participated in the flipped classroom to those who received the lecture curriculum on the annual American Board of Emergency Medicine (ABEM) in-training examination, (a 225-question standardized test lasting 4.5-hours and normed to all residents in the U.S. ACGME-accredited emergency medicine residency programs). The author controlled for differences in level of training by comparing resident scores by program level separately

(see Figure 2). In this figure, numbers represent post-graduate program year, whereas the letters represent study cohorts.

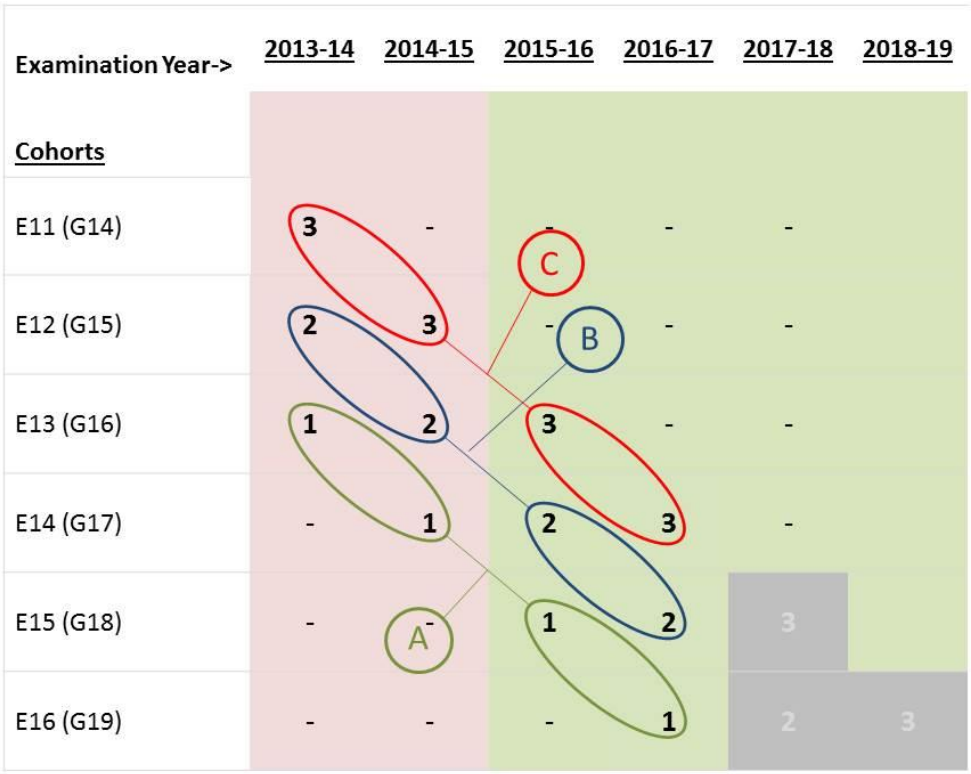

Figure 2: Comparison cohorts for ABEM in-training examination scores

The author also developed a program evaluation questionnaire to assess resident opinions of their educational experiences. The questionnaire simply asked residents to rate each component of the residency program on the quality of instruction and the value to their professional development. Response options for quality included 1=Poor, 2=Marginal, 3=Satisfactory, 4=Good, and 5=Excellent. The response options for value included 0=No value, 1= Minimal value, 2= Moderate value, 3= Considerable value, and 4= Great value. Residents were also asked how much time they spent (in hours) with

three types of learning materials: textbooks, online-instruction, and journals. The program evaluation survey questionnaire was distributed to all resident physicians in the study population.

Data Analysis

The author used paired comparisons (independent t-tests to compare exam scores for residents who experienced the lecture-based curriculum to those of residents in the new flipped classroom curriculum), while controlling for program level of training (i.e., interns from the new curriculum were compared to interns in the old curriculum, etc.). Figure 1 shows three statistical comparisons, one for each level of resident training (A= Program Year (PGY) 1s, B=PGY2s, and C=PGY3s).

Additionally, the author compared the program evaluation survey results between the residents who experienced the final year of the lecture curriculum (Academic Year 2014-15 (AY 2015)) to those who participated in the first year of the flipped classroom curriculum (Academic Year 2015-16 (AY 2016)). This ensured that at least two-thirds of the residents had experience with both curricula and were able to make fair comparisons. To avoid Type-1 error rates, a common problem when making multiple comparisons, the author redefined the p-values for consideration of statistical significance using the Bonferroni Adjustment.[65]

Ethical Considerations

To ensure the ethical instruction of the resident learners, this study assumed that the flipped classroom pedagogical approach would be equally effective as compared to standard lectures in educating resident learners. Residents received the same educational

core content of emergency medicine delivered using a different pedagogical approach. This education research study was determined exempt by The Ohio State University Institutional Review Board. No unique data was collected specific to this study, meaning the author used data that were required components of the residency program. All data remained deidentified aside from resident post-graduate training year.

Chapter 4. Results

Within this section of the research paper, the results obtained during implementation of the research methodology is presented. The data and associated analysis are presented to illustrate the effectiveness of the implementation of the flipped classroom pedagogical approach when compared to traditional lecture-based instruction. Secondarily, a program evaluation survey was performed to capture learner perception and satisfaction regarding the flipped classroom approach.

As mentioned previously, the study population involved emergency medicine residents who entered The Ohio State University emergency medicine residency program between 2011 and 2016. All emergency medicine residents at this institution within the study timeframe were included within the study. Of the 95 residents involved in the study, 50 were male and 45 were female. Additionally, residents completed their medical education at a wide variety of medical institutions across the United States of America.

Table 3 shows the results of the cohort comparison on the ABEM in-training examination scores from independent t-tests. As discussed earlier, the ABEM in-training examination is a standardized, 225 question assessment that is taken annually by all emergency medicine residents nationally. It is scored as a percentage correct, with a perfect score being 100. Table 3 shows both the mean ABEM in-training examination

scores by training level and the associated comparison within the cohorts to assess statistical significance. The author observed no statistical difference on the average in-training examination scores between residents who participated in the lecture-based curriculum and those who experienced the flipped classroom curriculum at any of the three post-graduate training levels (PGY 1-3).

Cohort -> Level at Time of Test	**Comparison**	**E-2011** (N=12)	**E-2012** (N=14)	**E-2013** (N=15)	**E-2014** (N=16)	**E-2015** (N=18)	**E-2016** (N=18)	**t**	**df**	**p**
PGY-1	A			70.5 (6.2)		71.3 (7.6)		0.16	65	.88
PGY-2	B		78.2 (6.0)		75.1 (6.5)			1.93	61	.06
PGY-3	C	81.0 (5.5)		78.1 (5.8)				1.78	48	.08

Table 3: Comparison of ABEM In-training Examination Scores by cohorts of residents who participated in the flipped classroom educational model and those who did not at different levels of training

Comparison A: Compares first year in-training exam scores between those who experienced the flipped classroom curriculum in year one of their residency and those who experienced a lecture-based curriculum.

Comparison B: Compares second year in-training exam scores between those who experienced the flipped classroom curriculum in year 2 of their residency and those who experienced a lecture-based curriculum in year 2 of their residency.

Comparison C: Compares third year in=training exam scores between those who experience the flipped classroom curriculum in year 3 of their residency and those who experience a lecture-based curriculum in year 3 of residency.

The emergency medicine residency program received program evaluation surveys from 28 of 45 residents (62.2%) in academic year 2014-15 (AY 2015) and from 19 of 49 residents (38.8%) in academic year 2015-16 (AY 2016). Twenty-seven resident physicians were eligible to participate in both surveys; however, only 9 of 27 residents (33.3%) completed both program evaluation surveys.

Program components ratings of quality and value are presented in Table 4. Program components that were used in one year or the other are shaded to indicate that no statistical comparison was made. Almost all program components except for *Mock Oral Boards* were rated higher in terms of both quality and value by residents in the flipped classroom; however, only *Adult and Pediatric Case Conferences* were rated significantly higher in quality but not value (Adult case conference: $t = -4.0$; $df = 45$; $p \leq 0.001$; es = -1.19; Pediatric case conference: $t = -3.7$; $df = 45$; $p = 0.001$; es = -1.10). The

Cohen's D effect sizes (es) related to the comparisons of quality for adult and pediatric case conferences are considered large.[66] *Small group* methods were rated the same across program years. Interestingly, *lectures* were rated higher in quality and value in the flipped classroom curriculum than they were in the lecture-based program. This result was statistically significant, but it was deemed to be a chance result.

Program Components		**AY 2015**		**AY 2016**					
		Mn	**SD**	**Mn**	**SD**	**t**	**df**	**p***	**es†**
Lecture: including Grand Rounds	Value	3.11	.92	3.68	.89	-2.15	39.7	.037	NA
	Quality	3.25	1.01	4.00	.75	-2.77	45	.008	NA
Small Group	Value	3.61	.79	3.84	.83	-0.98	37.2	.332	NA
	Quality	3.56	.93	3.68	.82	-0.48	44	.631	NA
Journal Club	Value	2.68	.95						
	Quality	2.38	1.06						
Procedures Lab	Value			3.95	.85				
	Quality			3.63	.90				

Continued

Table 4: Evaluation of program components by 28 of 45 (62.2%) residents from academic year 2015 (lecture curriculum) and 19 of 49 (38.8%) residents from academic year 2016 (flipped classroom curriculum).

Table 4 Continued

Program Components		AY 2015 Mn	AY 2015 SD	AY 2016 Mn	AY 2016 SD	t	df	p*	es†
Adult Simulations	Value			3.74	.73				
	Quality			3.68	.90				
Pediatric Simulation	Value			4.11	.57				
	Quality			3.89	.81				
Evidence-based Medicine	Value			2.53	.61				
	Quality			2.95	.91				
Trauma M&M	Value	3.46	.88	3.74	.81	-1.08	45	.287	NA
	Quality	3.43	.92	4.05	.78	-2.42	45	.020	NA
ED M&M	Value	3.89	.96	3.58	1.07	1.05	45	.298	NA
	Quality	3.71	.90	3.95	.78	-0.92	45	.362	NA
Adult Case Conference	Value	3.46	.92	4.11	.74	-2.53	45	.015	NA
	Quality	3.36	.83	4.26	.65	-4.00	45	.000	-1.19

Continued

Table 4 Continued

Program Components		AY 2015 Mn	AY 2015 SD	AY 2016 Mn	AY 2016 SD	t	df	p*	es†
Pediatric Case Conference	Value	3.41	.89	4.05	.780	-2.55	44	.014	NA
	Quality	3.29	.85	4.16	.688	-3.70	45	.001	-1.10
Review Sessions	Value	4.39	.74						
	Quality	4.50	.64						
Mock Oral Boards	Value	4.61	.57	4.11	.832	2.41	44	.020	NA
	Quality	4.39	.63	4.33	.686	0.32	44	.764	NA

*Adjusted p-value for significance = .05/10 or .005

†Cohen's D effect sizes are generally interpreted as follows: .2 = small effect, .5= medium effect, and .8=large effect.

Residents in the flipped classroom curriculum reported spending much more time (in hours) with outside learning resources as a whole (textbooks, online-learning resources, and journals combined) when compared to residents in the lecture-based curriculum (t = 2.68; df = 38; p = .011; es = -.852) (see Table 5 and Figure 3). The Cohen's d effect size (es) for the difference in average time spent with outside learning resources (all together) is considered large.[66] When compared separately, the amount of time spent on any one type of resource was not significantly different.

Time with Learning Materials (in Hrs)	**AY 2015**		**AY 2016**					
	Mn	**SD**	**Mn**	**SD**	**t**	**df**	**p***	**es†**
Textbooks	4.18	2.63	7.56	6.09	-2.19	22.2	.039	NA
Online Instruction	7.40	6.52	9.94	6.28	-1.22	36	.230	NA
Journals	3.00	2.47	4.33	3.71	-1.34	37	.189	NA
TOTAL Time	13.77	7.96	21.83	11.04	-2.68	38	.011	-.852

*Adjusted p-value for significance = .05/4 or .0125

†Cohen's D effect sizes are generally interpreted as follows: .2 = small effect, .5= medium effect, and .8=large effect.

Table 5: Estimates of time spent with learning materials from 22 residents in academic year 2015 (lecture-based curriculum) and 18 residents from academic year 2016 (flipped classroom curriculum).

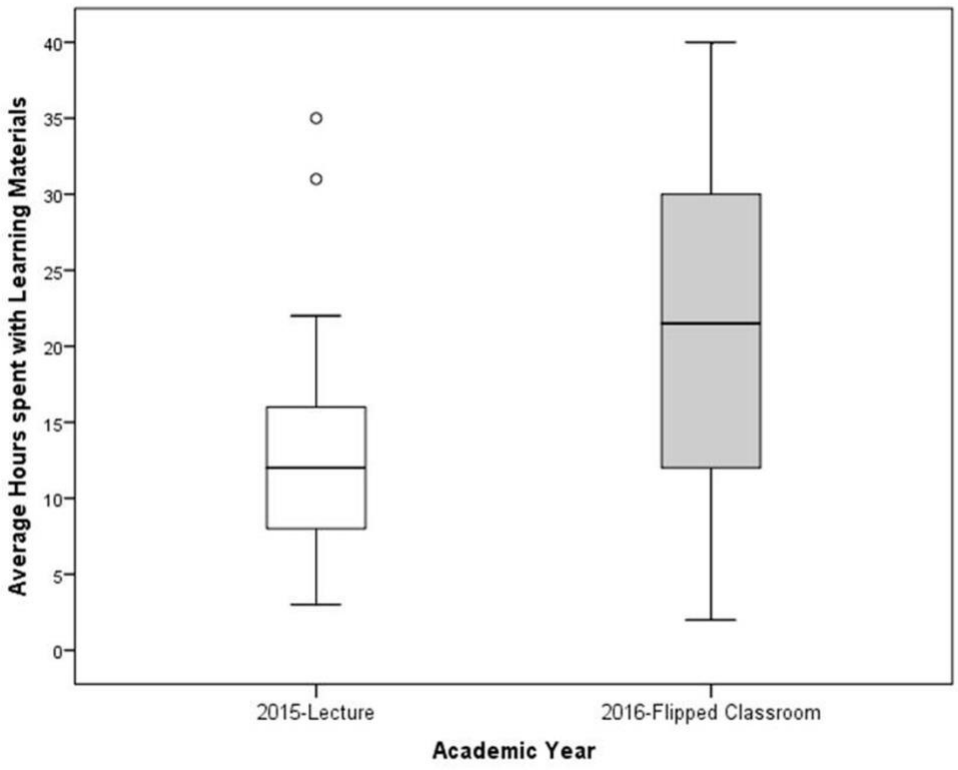

Figure 3: Box and whisker plot comparing average hours spent with outside learning materials such as textbooks, on-line learning resources, and journals across two groups of residents: one from a lecture-based curriculum year (2015) and one from a flipped classroom curriculum (2016).

Chapter 5. Summary, Discussion and Conclusion

The purpose of this final chapter is to provide a thorough discussion and interpretation of the results obtained in this study assessing the effectiveness of the flipped classroom pedagogical approach when compared to a traditional lecture-based curriculum. Additionally, within this chapter, the author will discuss the specific limitations of this research study and design. Finally, both the chapter and the research paper will conclude with a discussion of the overall conclusions deduced from the study and the associated literature review.

General Discussion

The adoption of a flipped classroom educational model for a large academic medical center's emergency medicine residency program did not have any major impacts on traditional outcomes, such as standardized test results or evaluations of program components. The findings associated with this study are consistent with those of others in the published literature on the use of the flipped classroom model in health sciences education.[33-34,67]

Residents in the flipped classroom model reported significantly greater amounts of time spent with outside learning materials, when time estimates were summed across three types of resources: textbooks, online learning resources, and journals. This is the most significant, yet not surprising finding in this study. Since preparation for small

group discussion during class meetings is an expectation of the program, the fact that residents are reporting more time using these resources is an expected outcome. Residents in the flipped classroom reported an average of almost double the amount of time they spent with textbooks along with roughly 25% increases in the amount of time they spent with online instruction materials and journals in order to prepare for the small group discussion and application.

Increases in time spent with preparation materials prior to face-to-face encounters may also explain resident's significantly higher quality ratings of case conferences; both pediatrics and adults. The author believes that because residents come prepared to discuss and apply their learning to these cases that they find this curriculum component to be of higher quality. The other feature of case conferences that residents seem to appreciate are the inclusion of rapid-fire case presentations with high-yield learning points.

In a large academic medical center emergency medicine residency program flipped classroom implementation, the use of self-chosen learning resources is encouraged. It is believed that this is appropriate at a graduate level of medical education, since preference for different types of learning resources are likely to be varied. In line with andragogical theory, graduate medical education learners are assumed to be self-directed and internally motivated.[11] Because of these factors, resident learners likely identify learning resources that best fit their learning needs. The Free Open Access Medical- Education (FOAM) movement has provided learners with a wealth of content material presented in a variety of ways from medical education experts around the world.[68] Although there was a large increase in average time spent with online resources,

the fact that a statistically significant increase was not demonstrated is probably attributable to the fact that the lecture group residents had also used these materials to supplement their education.

Increased use of FOAM resources combined with a flipped classroom approach to weekly didactic sessions is helping students at the post-graduate level to customize their education,[69] while reserving valuable group time for application of knowledge to real-world scenarios under the guidance of an expert.[70] The author expected to see higher ratings of both value and quality of most of the program components under the flipped classroom curriculum than the lecture curriculum; however, because so few of our respondents (9 of 27) experienced both program models, it is not sure that a true "curriculum change" effect was captured. In other words, residents rated what they know, without a reference to an alternative curriculum model.

Generally, the program evaluation provides some evidence for a successful implementation of a flipped classroom residency curriculum, which replaced the previous, almost completely lecture-based curriculum. The educational outcomes the author was able to measure through standardized tests and program evaluations remain stable across the two programs. While learners in our program seemingly have responded to the flipped classroom by adopting the required preliminary learning, the author is unable to confirm that the flipped classroom model is truly superior to traditional lecture methods with regards to educational efficacy.

Limitations

This research effort suffers a few limitations, the worst of which was incomplete program evaluation data from the residents, particularly in the second year of the study. While the study reached nearly a 40% return rate from residents in that academic year, the probability of selection bias was high. The author checked for selection bias and recognize that the respondents represented more PGY-1 and 3 residents. This may not accurately reflect the residency program as a whole, given the lower response rate among PGY-2 residents.

While the American Board of Emergency Medicine in-training examination tests the collective medical knowledge of resident trainees, this single, annual assessment of medical knowledge may not be sufficiently sensitive to detect the subtle differences in educational achievement obtained from two different curriculum models. While the flipped classroom method of teaching is designed for deeper learning and longer-term retention, an annual standardized test may not be the best measure of this type of learning.

Future studies using assessment instruments more specifically designed for measuring educational efficacy between the flipped classroom model and traditional lecture methods are needed. Furthermore, although exceptionally difficult and impractical, study designs that are effective at isolating the type of learning that occurs in classroom didactics from the type of learning that takes place in the clinical environment could contribute to further understanding the efficacy of different curriculum methods.

Recommendation

The systematic review of the literature revealed that when compared to other educational approaches, the flipped classroom pedagogical approach was equally effective. Although equivalent in educational outcomes to other educational methods, graduate medical education learners preferred the flipped classroom approach to other teaching methods. The results of this study align with those in the medical education literature. Since the flipped classroom approach is at least equally effective in learning outcomes and preferred by learners, the author recommends the use of the flipped classroom pedagogical approach in graduate medical education.

Conclusion

In conclusion, based on both the literature review and the results of this educational research study, the author believes that the flipped classroom model is as educationally effective as traditional lecture methods and holds promise for further exploration. Additional studies with more sensitive assessment instruments are needed to identify potential differences in educational efficacy between the flipped classroom model and traditional lecture methods.

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Appendix A. Full Search Strategies for All Included Databases

Database	Search Strategy Details
PubMed	Search input: (learning OR education OR teaching OR classroom OR classrooms OR pedagogy OR class OR Classes OR course OR courses) AND (flipped OR flip OR flipping OR inverted OR reverse OR Reversed OR "just in time") AND ("Internship and Residency"[Mesh] OR residency OR residents OR trainee OR trainees OR graduate medical education OR "house staff" OR interns OR GME OR ("medical education" AND graduate)) Search with mapping from PubMed Search Details: ("learning"[MeSH Terms] OR "learning"[All Fields]) OR ("education"[Subheading] OR "education"[All Fields] OR "educational status"[MeSH Terms] OR ("educational"[All Fields] AND "status"[All Fields]) OR "educational status"[All Fields] OR "education"[All Fields] OR "education"[MeSH Terms]) OR ("education"[Subheading] OR "education"[All Fields] OR "teaching"[All Fields] OR "teaching"[MeSH Terms]) OR classroom[All Fields] OR classrooms[All Fields] OR ("teaching"[MeSH Terms] OR "teaching"[All Fields] OR "pedagogy"[All Fields]) OR class[All Fields] OR Classes[All Fields] OR course[All Fields] OR courses[All Fields]) AND (flipped[All Fields] OR flip[All Fields] OR flipping[All Fields] OR inverted[All Fields] OR reverse[All Fields] OR Reversed[All Fields] OR "just in time"[All Fields]) AND ("Internship and Residency"[Mesh] OR ("internship and residency"[MeSH Terms] OR ("internship"[All Fields] AND "residency"[All Fields]) OR "internship and residency"[All Fields] OR "residency"[All Fields]) OR residents[All Fields] OR trainee[All Fields] OR trainees[All Fields] OR ("education, medical, graduate"[MeSH Terms] OR ("education"[All Fields] AND

	"medical"[All Fields] AND "graduate"[All Fields]) OR "graduate medical education"[All Fields] OR ("graduate"[All Fields] AND "medical"[All Fields] AND "education"[All Fields])) OR "house staff"[All Fields] OR interns[All Fields] OR GME[All Fields] OR ("medical education"[All Fields] AND graduate[All Fields]))
CINAHL Plus with Full Text	(learning OR education OR teaching OR classroom OR classrooms OR pedagogy OR class OR Classes OR course OR courses) AND (flipped OR flip OR flipping OR inverted OR reverse OR Reversed OR "just in time") AND (MH "Internship and Residency" OR MH "Interns and Residents" OR residency OR residents OR trainee OR trainees OR graduate medical education OR "house staff" OR interns OR GME OR ("medical education" AND graduate))
Embase (via Elsevier platform; using PICO search form)	('learning'/exp OR 'education'/exp OR 'education' OR 'education, distance' OR 'education, pharmacy' OR 'education, pharmacy, continuing' OR 'education, pharmacy, graduate' OR 'education, veterinary' OR 'pharmacy residencies' OR 'preceptorship' OR 'teaching'/exp OR 'computer-assisted instruction' OR 'programmed instruction' OR 'programmed instruction as topic' OR 'programmed teaching' OR 'teaching' OR 'teaching aid' OR 'teaching material' OR 'teaching materials' OR 'teaching method' OR 'teaching program' OR 'teaching programme' OR 'teaching, programmed' OR 'classroom'/exp OR classrooms:ti,ab OR class:ti,ab OR classes:ti,ab OR course:ti,ab OR courses:ti,ab) AND ('flipped classroom'/exp OR flipped:ti,ab OR flipping:ti,ab OR flip:ti,ab OR inverted:ti,ab OR reverse:ti,ab OR reversed:ti,ab OR 'just in time':ti,ab) AND ('medical education'/exp OR 'education, medical' OR 'education, medical, continuing' OR 'education, medical, graduate' OR 'fellowships and scholarships' OR 'internship and residency' OR 'medical education' OR 'medical instruction' OR 'medical program' OR 'medical programme' OR 'medical teaching' OR 'medical training' OR 'training, medical' OR 'resident'/exp OR 'interns and residents' OR 'resident' OR 'resident doctor' OR 'resident physician' OR 'resident surgeon' OR 'surgery resident' OR 'surgical resident' OR 'interns'/exp OR 'graduate medical education'/exp OR 'house staff':ti,ab OR gme:ti,ab OR 'residency education'/exp OR 'education, residency' OR 'residency education' OR 'residency training' OR 'resident training' OR 'residential education')

Web of Science Core Collection*	(learning OR education OR teaching OR classroom OR classrooms OR pedagogy OR class OR Classes OR course OR courses) AND (flipped OR flip OR flipping OR inverted OR reverse OR Reversed OR "just in time") AND ("Internship and Residency" OR "Interns and Residents" OR residency OR residents OR trainee OR trainees OR graduate medical education OR "house staff" OR interns* OR GME OR ("medical education" AND graduate))
ERIC (via EBSCO platform)	(learning OR education OR teaching OR classroom OR classrooms OR pedagogy OR class OR Classes OR course OR courses) AND (flipped OR flip OR flipping OR inverted OR reverse OR Reversed OR "just in time") AND ("Internship and Residency" OR "Interns and Residents" OR residency OR residents OR trainee OR trainees OR graduate medical education OR "house staff" OR interns* OR GME OR ("medical education" AND graduate))

*Databases and coverage included in core collections were Science Citation Index Expanded (1900-present), Social Sciences Citation Index (1900-present), Arts & Humanities Citation Index (1975-present), Conference Proceedings Citation Index- Science (1990-present), Conference Proceedings Citation Index- Social Science & Humanities (1990-present), Book Citation Index– Science (2005-present), Book Citation Index– Social Sciences & Humanities (2005-present), Emerging Sources Citation Index (2015-present), Current Chemical Reactions (1985-present; includes Institut National de la Propriete Industrielle structure data back to 1840), and Index Chemicus (1993-present).

Appendix B. Medical Education Research Study Quality Instrument (MERSQI) with corresponding article scoring. Reproduced from Reed et al. JAMA 2007: 298: 1002-1009.

Domain	MERSQI Item	Item Score
Study Design	1. Study design	
	Single group cross-sectional or single group posttest only	1
	Single group pretest and posttest	1.5
	Nonrandomized, 2 group	2
	Randomized controlled trial	3
Sampling	2. No. of institutions studied	
	1	0.5
	2	1
	>2	1.5
	3. Response rate (%)	
	Not applicable	
	<50 or not reported	0.5
	50-74	1
	≥75	1.5
Type of Data	4. Type of data	
	Assessment by study participant	1
	Objective measurement	3
Validity of evaluation instrument	5. Internal structure	
	Not applicable	
	Not reported	0
	Reported	1
	6. Content	
	Not applicable	
	Not reported	0
	Reported	1
	7. Relationships to other variables	

	Not applicable	
	Not reported	0
	Reported	1
Data Analysis	8. Appropriateness of analysis	
	Data analysis inappropriate for study design or type of data	0
	Data analysis appropriate for study design and type of data	1
	9. Complexity of analysis	
	Descriptive analysis only	1
	Beyond descriptive analysis	2
Outcomes	10. Outcomes	
	Satisfaction, attitudes, perceptions, opinions, general facts	1
	Knowledge, skills	1.5
	Behaviors	2
	Patient/health care outcomes	3
Total		