Original Investigation

Flipping Radiology Education Right Side Up

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Rationale and Objectives: In flipped learning, medical students independently learn facts and concepts outside the classroom, and then participate in interactive classes to learn to apply these facts. Although there are recent calls for medical education reform using flipped learning, little has been published on its effectiveness. Our study compares the effects of flipped learning to traditional didactic instruction on students' academic achievement, task value, and achievement emotions.

Materials and Methods: At three institutions, we alternated flipped learning with traditional didactic lectures during radiology clerkships, with 175 medical students completing a pretest on general diagnostic imaging knowledge to assess baseline cohort comparability. Following instruction, posttests and survey examinations of task value and achievement emotions were administered. Linear mixed effects analysis was used to examine the relationship between test scores and instruction type. Survey responses were modeled using ordinal category logistic regression. Instructor surveys were also collected.

Results: There were no baseline differences in test scores. Mean posttest minus pretest scores were 10.5% higher in the flipped learning group than in the didactic instruction group ($P = 0.013$). Assessment of task value and achievement emotions showed greater task value, increased enjoyment, and decreased boredom with flipped learning (all $P < 0.01$). All instructors preferred the flipped learning condition.

Conclusions: Flipped learning was associated with increased academic achievement, greater task value, and more positive achievement emotions when compared to traditional didactic instruction. Further investigation of flipped learning methods in radiology education is needed to determine whether flipped learning improves long-term retention of knowledge, academic success, and patient care.

Key Words: Flipped classroom; flipped learning; neuroimaging; clerkship; imaging; task value; achievement emotions.

INTRODUCTION

Medical students must master an extraordinarily large knowledge base and associated technical vocabulary in a very short time period. To this end, undergraduate radiology education has been largely dominated by didactic teaching methods designed to expeditiously deliver large volumes of information with a minimum student/instructor interaction (1). However, traditional large group lectures may not be ideal for the facilitation of development of the types of knowledge discovery and problem-solving skills required in radiology and other types of medical practice (2,3).

To address this problem, there is growing interest in exploring complementary medical instructional approaches that would more efficiently fill in existing knowledge gaps, foster application of knowledge stores, promote higher order thinking, and better prepare students for the challenges of clinical decision-making encountered in patient care contexts (4,5). Although many medical schools have begun to integrate problem- and team-based learning into their curricula, the transition to these interactive learning methods has been slow, and the use of didactic lectures still predominates (6). It is difficult to assess the learning outcomes associated with the ongoing slow reform in undergraduate medical education over the past decade, because medical educators have historically adopted varying definitions of what constitutes a problem-based learning curriculum, and not all have adopted the criteria advocated by Barrows, who developed the first problem-based learning curriculum at McMasters University (7). Moreover, estimates of the efficacy of problem-based learning in medical curricula vary (7,9,10).

Concerning the rate at which clerkship education is changing to incorporate more problem-based learning approaches, an informal survey of the institutions participating in this study

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revealed that didactics are still widely used, occupying between 50% and 95% of the available clerkship class time, perhaps because of both the relative efficiency of lectures in transmitting information to large groups and the faculty reluctance to adopt new teaching methods. In radiology instruction during the clinical years in medical education, 50% of institutions report exclusive use of lectures and textbooks (8). Concerns have also been raised regarding the economic viability of problem-based curricula for medical school class sizes greater than 100 because of the extensive resources needed to operate a fully problem-based curriculum (9,10). We suspect that lectures constitute the primary formal education method in medical clerkships in most US institutions and that it is common for clerkship students to receive didactic instruction by attending lectures designed primarily for resident staff.

The flipped classroom pedagogical approach encourages students to work independently to learn basic facts and concepts outside the classroom through varied methods, including reading, completing online education modules, and watching recorded lectures (11–15). This self-paced fact learning is supplemented by more dynamic, interactive classes in which the educator engages students in activities designed to develop skills related to application of these facts and concepts (16). The key features of this blended learning method involve both the use of class time to foster interactive application of knowledge and a shift in the educator's role from primarily transmitting facts to one facilitating deeper learning (17,18). The flipped classroom framework can be contrasted with more traditional instructional approaches in which classroom time consists of didactic lectures, and work outside the classroom involves either additional reading or working on problem sets before or after the didactic lecture. A key aspect of the flipped classroom involves moving basic material learning to self-paced sessions before class, thereby preserving class time for heightened student/instructor interaction and consolidation of the basic material.

An extension of the original flipped classroom idea, called flipped learning, has additional features, including an even more active and collaborative learning environment, additional options for self-paced learning, possibilities for peer-to-peer teaching, and provision of feedback to students for successful performance (19,20). In this arrangement, a particular advantage to instructors is the opportunity to identify concepts and skills that present difficulties for individual students, allowing adaptation of the teaching session to promote mastery of the more challenging skills and more strongly reinforce learning of basic facts and concepts (13).

Flipped classroom and flipped learning methods have been widely used in grade school, college, and graduate business education (19,21–25). Although not employed extensively in medical education, flipped approaches are being considered by many medical school curriculum reform efforts (26). Employing them seems sensible in a digitally oriented world with rapidly increasing biomedical knowledge, whose mastery may require more efficient instructional methods. Flipped learning in medicine allows students to apply recently acquired domain knowledge to problem-solving scenarios that simulate the clinical decision processes commonly required in patient care. This experiential and situated learning has high face validity with respect to physician training, in contrast to lectures that simply convey facts. Although we agree with the need to reimagine how medical education is delivered, very little has been published on the effectiveness of flipped learning approaches in medical education settings. It seems prudent to explore the effectiveness and student acceptability of this proposed reform before implementing such a major transformation in the delivery of undergraduate medical education.

While exploring the efficacy of flipped learning in fact and skill learning, it is also important to examine the emotional factors that influence learning in medical environments. Medical students' motivational beliefs and achievement emotions play a significant role in their academic achievement (27), perhaps by encouraging the types of more intense student participation that strongly correlate with academic performance (28,29). Although cognitive factors, including academic achievement and standardized test scores, receive strong emphasis in medical education, they are often of limited value in predicting future clinical performance (27,30). Medical students are consistently reminded that the process of learning is more important than the grades received. Even so, the National Residency Matching Program fosters an emphasis on quantitative performance data to discern levels of achievement, paradoxically emphasizing the weight of grades and standardized examination results. This situation should compel us to more closely examine personal factors that shape learning and performance in medical training, as their assessment may contribute to better prediction of an individual's class performance. To our knowledge, there are no previous studies examining how flipped learning influences emotional and experiential factors. We hypothesized that a flipped learning approach, centered on clinical diagnosis and management scenarios, will facilitate mastery of the radiology clerkship curriculum, strengthen motivation beliefs, and elicit more positive achievement emotions. Our experimental design compared the effects of flipped learning to didactic instruction on medical students' academic achievement, task value, and achievement emotions in a radiology clerkship course. We believe that comparing the outcomes associated with flipped learning and didactic instruction is an important first step, as it provides a relevant contrast between two operationally defined teaching methods, in the context of ongoing calls for replacement of didactics with flipped learning (6,26).

METHODS

A prospective cohort study was conducted from January 2014 to April 2015 at three medical schools, with Institutional Review Board approval at each site. We attempted to include a geographically diverse breadth of schools to account for possible regional influences. All participants were third or fourth year medical students enrolled in a 4-week radiology clerkship or radiology elective at one of the three participating