Computers & Education 139 (2019) 118–128

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Flipping the medical classroom: Effect on workload, interactivity, motivation and retention of knowledge

Rianne A.M. Bouwmeester[a,*], Renske A.M. de Kleijn[b], Inge E.T. van den Berg[c], Olle Th.J. ten Cate[d], Harold V.M. van Rijen[a], Hendrika E. Westerveld[e]

[a] Center for Education and Training, University Medical Center Utrecht, the Netherlands
[b] Centre for Teaching and Learning, Utrecht University, the Netherlands
[c] Department of Genetics, University Medical Center Utrecht, the Netherlands
[d] Center for Research and Development of Education, University Medical Center Utrecht, the Netherlands
[e] Department of Internal Medicine, University Medical Centre Utrecht, the Netherlands

ARTICLE INFO

Keywords:
Computer-mediated communication
Distance education and telelearning
Improving classroom teaching

ABSTRACT

Engagement with homework assignments is important to be able to actively process content during in-class activities in flipped classroom education. Active engagement with the content is assumed to promote deeper understanding and to improve retention of knowledge. This comparative case study aims to explore student workload during homework activities and examines in-class activities next to student motivation and their retention of knowledge in both traditional education and flipped classrooms.

This quasi-experimental study was conducted in a Hematology and Oncology course, which is scheduled in the second year of medical education, in Utrecht, the Netherlands. Students' self-reported study time in traditional classrooms (2014) and flipped classrooms (2015) were measured during one course with a daily online questionnaire and in-class activities were explored using an observation scheme and audio recordings. Cognitive evaluation theory was used to investigate student motivation by measuring perceived autonomy and competence (self-efficacy) of students at the end of the course. Knowledge retention and self-efficacy were (again) measured after 10 months.

The in-class observations suggested more interactivity in flipped classrooms. All participating students reported similar workload during the course, whereas exam preparation after flipped classrooms was significantly less time consuming. Students in flipped classrooms reported higher scores for self-efficacy, whereas perceived autonomy was comparable to students learning in traditional classrooms. Ten months after the course, retention of knowledge and self-efficacy scores showed no difference.

This study indicated that flipped classroom education required less time investment when preparing for the end-of-course exam and students perceived higher self-efficacy, which is relevant in the light of student stress and burn-out. However, comparison of long-term measurements (retention of knowledge and self-efficacy) showed similar outcomes for students in traditional classrooms and flipped classrooms. It would be interesting to learn whether students trained in flipped classroom education turn out to be better problem solvers in their future careers. For example, if the students in this study are better able to handle patient cases during their clinical rotations.

* Corresponding author. Biomedical Sciences, University Medical Center Utrecht, Universiteitsweg 100, 3508 GA, Utrecht, the Netherlands.
E-mail addresses: r.a.m.bouwmeester@umcutrecht.nl (R.A.M. Bouwmeester), R.a.m.dekleijn@uu.nl (R.A.M. de Kleijn), i.vandenBerg@umcutrecht.nl (I.E.T. van den Berg), T.J.tenCate@umcutrecht.nl (O.T.J. ten Cate), H.v.m.vanrijen@umcutrecht.nl (H.V.M. van Rijen), H.e.westerveld@umcutrecht.nl (H.E. Westerveld).

https://doi.org/10.1016/j.compedu.2019.05.002
Received 13 June 2018; Received in revised form 3 May 2019; Accepted 4 May 2019
Available online 05 May 2019

1. Introduction

Traditional lecture-based teaching approaches are a rather passive form of education in which teachers transfer knowledge to students (McLaughlin, Roth, Glatt, Gharkholonarehe, Davidson, Griffin, et al., 2014; Stuart & Rutherford, 1978). In traditional teaching approaches, the expertise of teachers might not be used effectively (van der Vleuten & Driessen, 2014; Wittich, Agrawal, Wang, Halvorsen, Mandrekar, Chaudhry, et al., 2017), as students are capable of reading and acquiring information on their own (Bergmann & Sams, 2012; McLaughlin et al., 2014). Fully understanding information and applying knowledge in new situations or in assignments is more difficult. In these situations, the presence of a teacher is crucial, because teachers can support critical thinking and show students how to solve problems (Anderson, Rourke, Garrison, & Archer, 2001). In the flipped classroom model, students acquire foundational knowledge for example through watching web-lectures and reading study books (Bouwmeester, de Kleijn, ten Cate, van Rijen, & Westerveld, 2016), before deepening and applying this knowledge during in-class assignments such as analyzing case studies and undertaking collaborative group work (Bonnes, Ratelle, Halvorsen, Carter, Hafdahl, Wang, et al., 2017; McLaughlin et al., 2014; Moffett, 2015; Prober & Khan, 2013).

1.1. Effects of flipped classroom education

Empirical studies in medical and nutrition education including a recent systematic review on the implementation of flipped classrooms have shown improvement in student satisfaction and engagement (Gilboy, Heinerichs, & Pazzaglia, 2015; Prober & Heath, 2012; Street, Gilliland, McNeil, & Royal, 2015). Reported effects on knowledge and skills are less decisive. However, a systematic review in medical education concluded that flipped classrooms were at least as effective as traditional education (Chen, Lui, & Martinelli, 2017), whereas a meta-analysis in the field of health profession education showed a significant improvement in performance after attending flipped classrooms compared to participation in traditional education (Hew & Lo, 2018). Interestingly, most of these studies investigated short-term learning outcomes. One study in Psychobiology showed that students in flipped classrooms were better adapted to collaborative learning strategies and showed enhanced metacognition, but these effects did not last (Van Vliet, Winnips, & Brouwer, 2015). Investigating longer-term effects and knowledge retention will provide more insight into the sustainable effects of flipped classrooms (Akçayır & Akçayır, 2018; Chen et al., 2017). Contradictory findings regarding performance were also reported in a comparative study in the field of anatomy, in which the researchers noticed that students in flipped classrooms performed equally well on lower cognitive assignments, but better on more cognitively complex items (Morton & Colbert-Getz, 2017). These authors therefore suggest that future studies should distinguish lower and higher levels of cognition in learning outcomes, which is therefore addressed in the present study.

1.2. The role of student motivation in flipped classrooms

One of the underlying mechanisms contributing to increased performance in flipped classrooms is the intrinsic motivation of students (Persky & McLaughlin, 2017; Sergis, Sampson, & Pelliccione, 2018). Following cognitive evaluation theory (a sub theory of self-determination theory), motivation can be enhanced through fulfilling the need for autonomy and competence (Deci & Ryan, 1980). With regard to flipped classrooms, autonomy might be supported by the freedom to choose from different study materials when preparing for class and planning these activities in students' own time and pace (Bouwmeester et al., 2016). However, the short timeframes in which students need to prepare might hamper this autonomy (Deci & Ryan, 2000; Street et al., 2015).

With respect to competence, formative testing can be implemented in flipped classrooms. Formative testing with extensive feedback as part of pre-class preparation could stimulate student confidence, because the feedback can provide students with insight into their own strengths and help them determine gaps in their knowledge (De Kleijn, Bouwmeester, Ritzen, Ramaekers, & Van Rijen, 2013). Other ways to enhance competence is to provide students with positive feedback and acknowledge their contribution during in-class activities (Deci & Ryan, 2000; Persky & McLaughlin, 2017).

1.3. In-class activities

Studies in higher education regarding flipped classrooms often focus on student satisfaction and learning outcomes (Chen et al., 2018). Apart from being interactive, little is known about the in-class activities that might cause these improved learning outcomes. The most frequently mentioned learning activities in literature reviews of K-12 education and social sciences are discussions, small-group activities, problem solving, brief reviews and student presentations (Akçayır & Akçayır, 2018; Lo & Hew, 2017). Behavioral studies could further enhance the knowledge and understanding of flipped classroom education, but these are still lacking. A search in literature identified a few observational studies, most of which focused on college students and their classroom behavior (Volpe, DiPerna, Hintze, & Shapiro, 2005). Nunn (1996) empirically studied the correlation between discussion-related teaching techniques and student participation. This study indicated that asking questions was the most frequently used technique and resulted in increased participation of students. Other techniques such as praising students and correcting wrong answers were used to a much lesser extent.

1.4. Concerns regarding flipped classrooms

The most salient concerns about the implementation of flipped classrooms are the amount of work and time that are needed to convert the course design and the requirement of new learning materials (Moffett, 2015; Snowden, 2012), as well as the costs related to this change (Spangler, 2014). It is stated that some educators also need additional training in order to learn how to effectively create a flipped classroom (Shimamoto, 2012). Another issue is that some students do not engage with the out-of-class activities and come to class unprepared, which leads to the in-class activities being impeded (Sayeski, Hamilton-Jones, & Oh, 2015). This can result from low motivation, but might also be related to workload (Khanova, Roth, Rodgers, & Mclaughlin, 2015). It is speculated that student workload in a flipped classroom is higher compared to learning in traditional classrooms (Bouwmeester et al., 2016; Moffett, 2015; Prober & Khan, 2013). One of the reasons may be that educators are more inclined to present excessive content as online study material (Moffett, 2015; Wagner, Laforge, & Cripps, 2013), and schedule additional interactive sessions during classroom hours (Street et al., 2015). A second reason might be the lack of instruction to students on how to use the various online study materials (Bouwmeester et al., 2016; Wanner & Palmer, 2015).

1.5. Present study

The purpose of the current quasi-experimental study is (1) to explore medical student workload during homework activities, (2) to examine in-class activities, (3) to investigate student motivation, and (4) to determine retention of knowledge in flipped classrooms, all in comparison with traditional lecture-based education. We hypothesize that medical students participating in the Hematology and Oncology course of Utrecht University, the Netherlands, experience an increased workload during the course, but that this increased workload may lead to a reduced time investment when studying for the end-of-course exam. The increased preparation of students may also result in more in-depth discussions with peers and teachers during classroom sessions. As students are able to discuss on a more advanced level, and provide more input during classroom discussions, students in flipped classrooms may report higher self-efficacy scores and achieve higher grades. Moreover, since students are actively challenged to apply their knowledge during classroom sessions, it is also assumed that this knowledge will retain better, meaning that they may perform better on cognitively complex questions during the retention exam.

2. Methods

2.1. Educational setting

This quasi-experimental study was conducted in a Hematology & Oncology course, during two consecutive years. The course is part of a 4-year graduate-entry medical program. The course load was planned as part-time, amounting to 20 h per week (i.e. 50% of students' time). In January 2014, the course was given in a traditional lecture-based design, meaning that students could attend lectures to acquire new knowledge. During two of the classroom sessions a real-life patient was invited into the classroom.

In January 2015, this course was mostly taught using a flipped classroom model, while one of the topics remained in the traditional classroom approach (due to organizational constraints). Students were asked to prepare for flipped classroom sessions in particular by watching recorded lectures and reading text in the online learning environment (Blackboard). The acquired knowledge was prerequisite to participate actively during in-class sessions in which assignments were to be solved and three real-life patients were presented. Teachers were instructed not to repeat content scheduled as pre-class preparation. For comparison, the course content, learning goals and number of classroom sessions were identical for both cohorts.

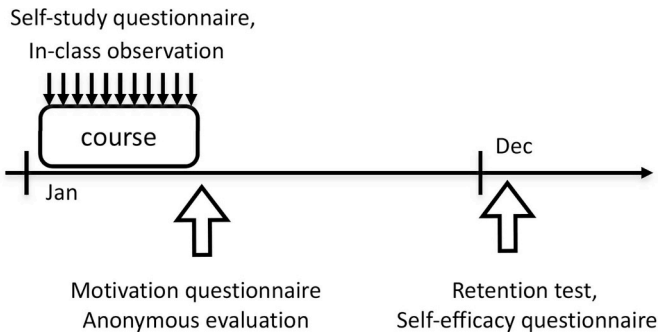

Fig. 1. Overview of data collection. Self-study questionnaire (small arrows) represents the daily, online questionnaire to report workload. Motivation questionnaire represents the questionnaires used to determine parameters of cognitive evaluation theory; autonomy and competence (indicated with the first large arrow). The long-term effects are indicated with the second large arrow represent the retention test and self-efficacy questionnaire).

2.2. Participants

In 2014, 28 students (70% of the full cohort of 40 students) volunteered to participate in this study. An information letter and informed consent form provided participants with information about data handling and study goals. Students were on average 24.1 (SD = 3.6) years old, and 64% were female. This is representative for the complete cohort. In 2015, 36 students (90% of 40) consented to participate in this study. These students were 23.1 (SD = 1.1) years of age, and 67% were female. The average grades for courses similar to this course were 7.41 (SD = 0.59) for the participating students in 2014 and 7.30 (SD = 0.73) for the participants in 2015. The researchers did not retrieve any information about ethnicity or disability status of the students. Participation was voluntary and no incentives were given. In line with the requirements from the Ethical Review Board, no explicit information is available about the students who chose not to participate.

2.3. Data collection

An overview of data collection is shown in Fig. 1. During the course (January 2014 and 2015), in-class observations were performed and students were invited to report their daily workload in a self-study questionnaire. At the end-of-course exam (± February 1st), students indicated their perceived autonomy and self-efficacy, a measure for competence, and filled out the anonymous course evaluation (amongst other items questions regarded perceived time investment and workload). Ten months after the course (± December 2014 and 2015), students took a retention test and again filled out their perceived self-efficacy of learning goals of the course.

2.3.1. Workload for students

Participants were invited to fill out a daily online questionnaire about the time spent on homework activities (i.e. self-study questionnaire in Fig. 1). In 2014, students were provided with books, CD-ROMs, case studies, video recordings of lectures (available after class), and links to recommended websites.

In 2015, the same course content was provided. Students could use the same books and links to recommended websites. However, web-lectures (recordings from previous years or newly recorded web-lectures) were now available before class, such that students could prepare for in-class application of this knowledge. Case studies, which were available as voluntary homework after the lectures in 2014, were discussed during classroom sessions in 2015. At the request of students, recordings of this year's lectures (except for lectures with real-life patients) were available after class.

As a standard procedure for quality control, the complete cohort of students is always invited to fill out an anonymous course evaluation form at the end of a course. Amongst other things, students can indicate the average number of hours spent on the course outside of the classroom. Students' perception of workload was asked on a scale ranging from 1 to 5; with 1 meaning too low, and 5 meaning too high. This anonymous evaluation was filled out by 35 students attending traditional education, and 39 students participating in flipped classrooms. Since this evaluation is anonymous, it is not possible to extract the answers from students with and without informed consent and perform further statistical analyses.

2.3.2. In-class activities

To the best of our knowledge, validated observation schemes to determine teacher and student activities are not yet available in literature. To that end, three authors (RB, RdK and OtC) discussed literature readings about in-class activities (Nunn, 1996; Volpe et al., 2005), and designed a protocol for analysis. The following in-class activities were expected from teachers: (1) Transmitting factual information, i.e. information that is covered in books (and web-lectures), (2) Explaining in-depth information, i.e. information that students should understand after application of their previously acquired knowledge in case studies, and information that is known by medical professionals such as co-morbidities, (3) Asking questions to the student, (4) Answering student questions and supplementing student answers, (5) Providing feedback, i.e. giving directions to student thinking and giving compliments, and (6) Giving instructions i.e. non-content procedural information.

Three activities for students were distinguished; asking questions, responding to questions, and discussing with peers. Silence was also measured.

A researcher was silently present and made audio recordings of lecture-based traditional and flipped classrooms (in total 27 contact sessions per cohort). Meet-the-Expert sessions, practical anatomy labs and lessons in which real-life patients were present were excluded from analysis. Consequentially 17 classroom sessions per cohort, taught by nine different teachers remained. The in-class activities were expressed as average frequency of occurrences. A second observer was present in five lessons with five different teachers. This second observer's scheme was compared to the scheme of the initial observer as an internal control. The agreement between the observers was 69.3% for the 2014 cohort, and 83.2% for the 2015 cohort.

Further analysis was conducted on audio recordings of teachers teaching the same topic in the traditional approach in comparison to the flipped classrooms. From these recordings, the duration of each activity was measured in minutes. The average percentage of total classroom time spent on each activity was calculated. The analysis of audio recordings was conducted for 5 different teachers and the analysis was checked in an audit procedure by an independent educational researcher. The auditor indicated that in rare occasions it was difficult to hear what the teacher was saying, when he/she was at the other end of the classroom helping a student. Still, the voices were recorded quite well for the majority of the time. In addition, the auditor indicated that the distinction between the transmission of factual knowledge and explanation of in-depth information was most difficult, since he was not an expert in the field of Hematology and Oncology. However, the description of both activities was sufficient to make this distinction.

2.3.3. Motivation parameters

Following cognitive evaluation theory, students' perceived autonomy and competence as needs for motivation were explored at the end of the course. Students' perception of self-efficacy in achieving the learning goals of the course was used as operationalization of perceived competence (using a scale from 0 to 100%). One example of the 14 items from this questionnaire is; *'How confident are you at this particular moment to: "indicate if genetic research is needed for a patient that was recently diagnosed with a mamma carcinoma*". The self-efficacy questionnaire was also filled out after the retention exam to determine long-term perception of competence.

Autonomy was determined with the *Self-Regulation Learning Questionnaire* from Black and Deci (2000), using a scale from 1 to 7 (meaning 1 = not at all true to me – 7 = very true to me). This questionnaire is comprised of 12 items and distinguishes two subscales; autonomous and controlled reasons for learning. A validation study indicated that the reliability of the two subscales were 0.70 for controlled reasons for learning and 0.78 for autonomous reasons for learning. The construct validity for the two subscales were $r = 0.33$, $p < 0.01$, and $r = 0.27$, $p < 0.01$, respectively (Williams & Deci, 1996).

2.3.4. Knowledge retention

Participants were invited back to take a knowledge test 10 months after the end-of-course exam and were instructed not to study for this retention test. Students who had not passed the end-of-course exam were excluded from analysis, because the re-sit exam was scheduled shortly before the retention test. The retention test for students in traditional education and students in flipped classrooms was identical and composed of 56 multiple-choice questions. In total, 47 questions covered subjects that were also taught in flipped classrooms in 2015 and 9 of these questions covered a topic that was not flipped, the scores for which served as an internal control. An external expert teacher determined the complexity of all questions in the retention test following the categories in Bloom's taxonomy (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956; Krathwohl, 2002). In total, 17 questions (12 concerning flipped topics and 5 concerning the control topic) required knowledge and 39 questions (35 flipped and 4 control) required application and analysis skills.

2.4. Statistical analysis

Means and standard deviations were calculated with descriptive statistics, using SPSS 23.0 (IBM). When a significant difference was measured, Cohen's *d* was calculated using https://www.uccs.edu/~lbecker/ to determine the effect size. The average workload of students (self-reported time spent preparing the flipped topics and the control topic) in traditional and flipped classrooms were compared using ANOVAs. To this end, the workload of students was averaged per week and, based on these numbers, an average workload during the course (weeks 1–4), as well as the week preceding the exam, were calculated for both cohorts.

In-class observation schemes were used to calculate the frequency (number of occurrences) of each teacher and student activity. For individual lessons, the total number of different teacher and student activities was tallied and the average frequencies per cohort were compared using paired T-tests. For five lessons, it was determined how much time was spent on each activity. Since the duration of lessons deviated from the scheduled 45 min (range 33–62 min in traditional classrooms and 43–61 min in flipped classrooms), classroom time was calculated as the percentage of total classroom time. Significance testing was not conducted as we considered the number of included classrooms too low.

For the motivation parameters (self-efficacy and autonomy), reliability was determined by calculating Cronbach's alpha. The reliabilities of these questionnaires were 0.791 for self-efficacy, 0.692 for autonomous, and 0.780 for controlled reasons for learning. Subsequently, scores on the questionnaires were compared using T-tests.

Retention of knowledge was compared using the percentages of correct answers on 'knowledge' and 'application' questions for each student in the retention test. The average scores on 'knowledge' and 'application' questions were compared using T-tests.

3. Results

3.1. Workload for students outside the classroom

Responses to the standard retrospective, anonymous end-of-course evaluations indicated that students in traditional education spent approximately 11.4 (SD = 1.4) hours per week on homework, whereas students attending flipped classroom spent 13.0 (SD = 1.5) hours per week. The students in flipped classrooms also seemed to perceive a higher workload (M = 3.6, SD = 0.7) compared to students in traditional education (M = 3.2, SD = 0.6).

The responses to the online self-study questionnaire were used to compare students' average workload during the course. During the first four weeks of the course, time spent on homework activities was similar in both cohorts. Students in traditional education spent 1.2 (SD = 1.0) hours per day on average and students in flipped classrooms 1.5 (SD = 0.9) hours per day ($F(1,1) = 2.14$, $p = 0.15$).

In the week preceding the exam, time investment in the flipped classrooms was significantly less compared to students learning in traditional education - on average 4.0 (SD = 3.4) hours per day in flipped classrooms versus 6.5 (SD = 2.6) hours per day in traditional education ($F(1,1) = 8.50$, $p = 0.005$, $\eta^2 = 0.15$).

3.2. In-class activities

Fig. 2 shows the average occurrence of in-class activities for teachers and for students. Fig. 2a indicates that teachers in traditional classrooms more frequently explained factual information (information also to be found in books and other homework materials), 7.5

(SD = 3.9) versus 3.3 (SD = 5.2) times per lecture (t(16) = 2.63, p = 0.02). In flipped classrooms teachers explained significantly more in-depth information (M = 9.0 (SD = 7.0); M = 1.5 (SD = 1.7), t(16) = -4.57, p= < 0.01). Teachers also appeared to ask more questions (M = 25.8 (SD = 25.1); M = 14.1 (SD = 16.2), t(16) = -1.74, p = 0.10) and provide more answers to students (M = 30.8 (SD = 19.0); M = 23.6 (SD = 14.3), t(16) = -1.50, p = 0.15), but these differences were not significant. Fig. 2b illustrates that students in flipped classroom appeared to ask more questions (M = 24.4 (SD = 16.5); M = 19.5 (SD = 11.9), t(16) = -1.46, p = 0.17) and to provide answers more frequently (M = 26.2 (SD = 24.9); M = 16.6 (SD = 21.2), t(16) = -1.34, p = 0.20). These student activities were not significantly different.

Analysis of the audio recordings of five lessons shows that in traditional classrooms teachers spent the majority of their time on transmitting factual information and explaining in-depth information (37% and 41% respectively, see Table 1). Ten percent of the time was spent on answering questions and hardly any time was spent on asking questions, providing feedback, giving instruction, or silence.

In flipped classrooms, teachers spent a substantial proportion of their time on explaining in-depth information (32%), while transmission of factual information only occupied approximately half of that time (18% of total time). Asking questions to students, answering student questions, and providing feedback to students now took approximately the same amount of time (9%, 10%, and 11% respectively) compared to 1%, 10%, and 2% respectively in traditional education. The overall activity of students in flipped classrooms increased. Students still spent ± 5% of classroom time asking questions, but an additional 6% of classroom time was spent discussing with peers and responding to questions put forward by the teacher. Even though the number was too small to test for statistical significance, the findings suggest that on average in the flipped classrooms teachers spent less time on transmitting factual knowledge (rather than explaining in-depth information) and more on asking questions and providing feedback.

3.3. Motivation parameters

The basic needs supporting intrinsic motivation are a sense of autonomy and competence. The self-reported scores on autonomous reasons for learning (M = 5.61 (SD = 1.0); M = 5.69 (SD = 0.9), t(41) = -0.28, p = 0.78) and controlled reasons for learning (M = 3.90 (SD = 1.2); M = 4.41 (SD = 1.0), t(37) = -1.66, p = 0.11) were comparable at the end-of-course exam (Fig. 3a). As shown in Fig. 3b (bars on left-hand side), students rated their self-efficacy significantly higher in flipped classrooms (M = 58.9% (SD = 10.4); M = 64.9% (SD = 10.0), t(41) = -2.09, p = 0.04, η^2 = 0.580).

3.4. Long-term effect of flipped classrooms

The initially higher self-efficacy scores after attending flipped classrooms reduced to approximately half by the time students took the retention test 10 months later. This level of competence is comparable to the scores reported by students in traditional education, (M = 37.3 (SD = 13.5); M = 34.2 (SD = 14.3), t(43) = 0.76, p = 0.45), indicating that students in flipped classrooms felt as competent in performing learned tasks as students in traditional education 10 months after the course.

The overall scores on the retention exam are comparable in the two cohorts. A more in-depth analysis of the retention exam, shown in Fig. 4, indicates that both cohorts performed equally well on questions that required foundational knowledge (M = 48.8 (SD = 13.3); M = 44.1 (SD = 11.4), t(36) = 1.23, p = 0.23) and questions requiring application skills (M = 40.9 (SD = 6.0); M = 41.3 (SD = 6.9), t(41) = -0.18, p = 0.86). Scores on the non-flipped topic also showed no significant differences (M = 65.5 (SD = 16.1); M = 56.4 (SD = 20.3), t(42) = 1.65, p = 0.11), indicating that students performed equally well on the retention test when they did not refresh their knowledge in the time between the end-of-course exam and this retention test 10 months later.

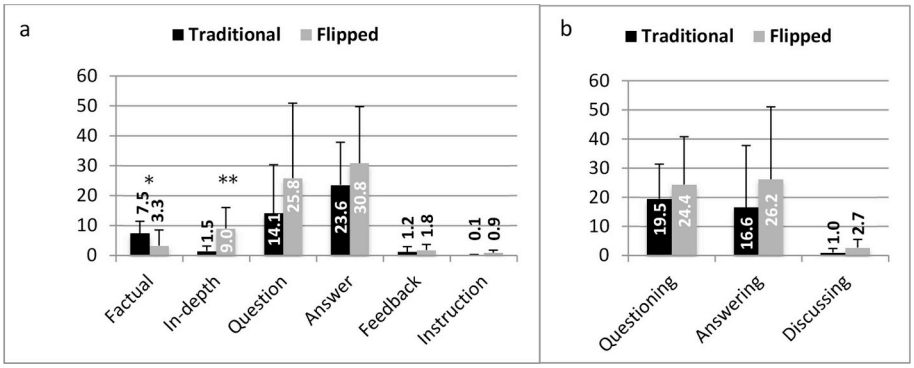

Fig. 2. Average occurrence of teacher and student activities in class. The average number of (a) teacher and (b) student activities of 17 lectures from 9 different teachers are shown. *p < 0.05, **P < 0.01.

Table 1
Duration of in-class activities in average percentage of total classroom time, based on audio recordings. Analyses include 5 traditional and 5 flipped classroom sessions.

% of total classroom time	Traditional classroom		Flipped classroom	
	Mean (SD)	Range	Mean (SD)	Range
Teacher activity				
Transmitting factual information	36.8 (24.3)	10.2–65.7	18.3 (13.7)	6.1–33.5
Explaining in-depth information	41.1 (32.6)	4.5–75.4	31.8 (12.8)	23.9–54.3
Asking questions	1.3 (1.5)	0.1–3.2	8.9 (3.3)	5.7–13.3
Answering questions	10.0 (2.5)	7.5–13.4	10.4 (3.4)	5.9–15.3
Providing feedback	2.0 (2.3)	0.0–5.8	10.6 (5.6)	4.7–19.6
Giving instruction	2.3 (2.7)	0.3–6.9	5.2 (1.2)	3.5–6.8
Silence	1.7 (1.2)	0.5–3.1	4.1 (4.3)	0.2–10.9
Student activity				
Questioning	4.0 (1.6)	2.0–6.0	4.6 (1.0)	3.7–6.2
Responding	0.9 (1.0)	0.0–2.4	5.5 (3.8)	1.8–11.7
Discussing	0.0 (0.0)	0.0–0.0	0.6 (1.3)	0.0–2.9
Total	100.1%		100%	

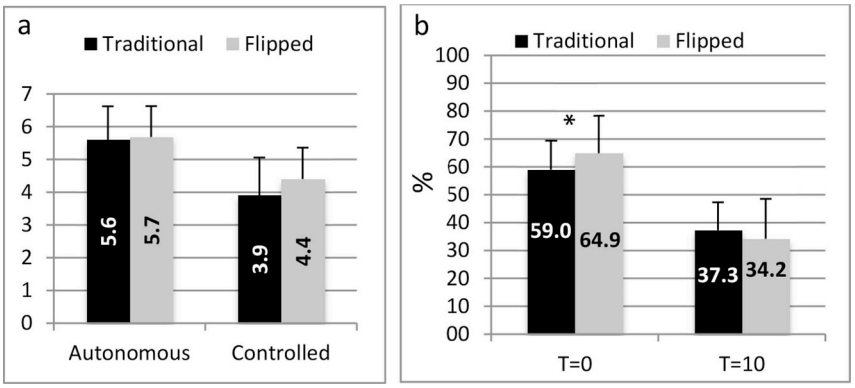

Fig. 3. a, b. Average perception of autonomy and self-efficacy a) Autonomy (autonomous and controlled reasons for learning (1–7)) and b) self-efficacy (0–100%) at the end of the course (T = 0) and 10 months later (T = 10). $p < 0.05$.

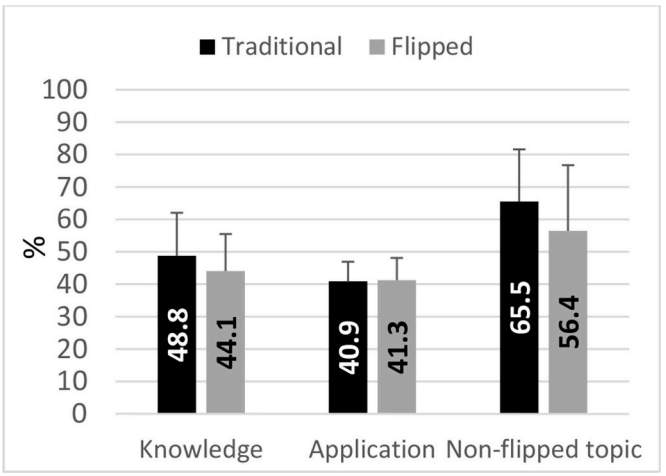

Fig. 4. Scores on knowledge tests divided in knowledge (K = 12), application questions (K = 35) and a non-flipped topic as a control (K = 9).

4. Discussion

Research on the implementation of flipped classrooms has shown increased satisfaction and often improved performance on end-of-course exams (Street et al., 2015). Thus far, the effect on student workload, teacher and student activities in class, and long-term retention of knowledge has only been speculated about. This study provides quasi-experimental evidence that students' actual time

investment outside flipped classrooms is similar to the workload during traditional education. However, the usual peak before the exam was significantly lower in flipped classrooms and, more importantly, students' ratings of self-efficacy were significantly higher at this time. The in-class observations suggested that teachers transmitted less factual information, instead teachers seemed to ask more questions and provided students with more feedback. Long-term effects in this study showed no significant difference on retention of knowledge or the perception of competence when compared to traditional education.

4.1. Workload for students

It has been speculated that student workload in flipped classrooms is likely to increase (Akçayır & Akçayır, 2018; Hung, 2015). Strict instructions towards educators and clear communication clarifying teacher expectations might have prevented a significant overload for students in our study (Wanner & Palmer, 2015), even though the summaries of the end-of-course-evaluations still seem to detect a slight increase in perceived workload. An underlying cause for perceived higher workload might be the fact that flipped classroom students specifically asked for the publication of lecture recordings. With these recordings, students might have finalized their lecture notes, as they were used to during traditional education (Chen, Wang, Kinshuk, & Chen, 2014; Porcaro, Jackson, McLaughlin, & O'Malley, 2016), however viewing both web-lectures and recordings of live lectures obviously takes more time and was not anticipated beforehand.

A more interesting finding is the significantly lower time investment in the week preceding the exam. We hypothesized that proper preparation and active participation during classroom sessions would result in reduced cramming before the exam. This hypothesis was confirmed as students in flipped classrooms spent approximately 4.0 h per day studying for the exam, whereas students in traditional education needed on average 6.5 h per day.

4.2. In-class activities

Knowing what actually happens inside the classroom when flipping is applied, might help to understand how outcome measures such as improved performance and student satisfaction are related to the educational approach. In flipped classrooms, it is expected that students have a prepared mind and participate actively (Akçayır & Akçayır, 2018; Lai & Hwang, 2016). Measurements of the duration of in-class activities indicated that more time was occupied by student activities in flipped classrooms compared to traditional education. The total percentage of time filled by students approximately doubled (from 4.9% to 10.7%). In addition, the percentage of classroom time occupied by the transmission of factual information reduced from 37% in traditional classrooms to 18% in flipped classrooms. These in-class observations suggest that the educational approach indeed stimulates interaction (Akçayır & Akçayır, 2018; Galway, Corbett, Takaro, Tairyan, & Frank, 2014), mainly between students and the teacher. This was probably caused by teachers asking more questions or because they provided more feedback to the students. This latter finding supports the idea that providing students with frequent feedback positively influences student learning (Deslauriers, Schelew, & Wieman, 2011; McLaughlin et al., 2014), as (positive) feedback is known to stimulate competence in students (Deci & Ryan, 2000; Persky & McLaughlin, 2017). Still, the question remains whether the improvements observed in flipped classrooms are the result of the inverted pedagogy, or whether these improvements are the effect of active learning strategies in general (Jensen, Kummer, & Godoy, 2015).

4.3. Motivation parameters

An important factor for improved performance is student motivation. Cognitive evaluation theory states that motivation is influenced by two factors; autonomy and competence (Deci & Ryan, 1980). Prior to data collection, we did not have a decisive hypothesis about autonomy. On the one hand, we assumed that students might experience increased autonomy, because they would have more freedom in using study materials aligned with personal preference (Bouwmeester et al., 2016; Street et al., 2015). In contrast, the obligation to be prepared for each classroom might still have given the impression of being controlled. Nevertheless, mandatory preparation might have reduced the opportunity to procrastinate, explaining why students needed less cramming in the week preceding the exam.

Regarding students' perception of competence, it was hypothesized that students in flipped classrooms would be better able to perform the tasks described as the learning goals of the course. This assumption was confirmed and implies that the method of flipped classrooms, i.e. actively processing the obtained knowledge in class, is indeed an effective learning method, since students did not increase their overall time investment. This finding also confirms other studies devoted to flipped classrooms showing improved performance on end-of-course exams (Hew & Lo, 2018; Street et al., 2015). The fact that self-efficacy scores at the retention exam dropped to levels similar to scores by students attending traditional education, supports the idea that perception of self-efficacy is task-related. During the retention test, students were encouraged to actively process course information dealt with 10 months earlier. In both groups, students felt less competent during this retention test. Since the scores on the retention test and the self-efficacy questionnaire were similar for both cohorts, we might speculate that students are well aware of their own capacity and therefore able to indicate accurate perceptions of competence.

4.4. Retention of knowledge after flipped classrooms

As demonstrated by Morton and Colbert-Getz (2017), students in flipped classroom are suggested to be equally effective in acquiring knowledge compared to students in traditional education. However, their study showed that these students are better able

to apply knowledge in an exam at the end of the course. The current study showed that flipped classroom students' retention of knowledge is comparable to the retention of knowledge by students in traditional education. We found no differences in the type of knowledge that was retained, as students performed equally well in questions involving factual understanding and questions requiring the application of this knowledge. Due to organizational constraints, one topic in this course was not taught using the flipped classroom approach. In the retention test the scores on this non-flipped topic were used as an internal control and indicated that students from both cohorts performed equally well. We therefore conclude that retention of knowledge after flipped classrooms is similar to the retention of knowledge after traditional education, when students are not allowed to refresh their knowledge. This is in line with findings of Van Vliet et al. (2015) who demonstrated that the enhanced critical thinking skills of second-year Psychobiology students was no longer evident after 5 months.

As students in flipped classrooms are challenged to acquire content knowledge on their own, and these students process this knowledge more actively during classrooms sessions, flipped classroom students might be better able to refresh their knowledge, for instance when these medical students start their clinical rotations (Chen et al., 2018). Future studies could investigate whether the time needed to retrieve knowledge that was learned in the past is less for students who gained this knowledge using active learning strategies such as the strategies used in flipped classroom approach.

5. Conclusion and practical implications

Flipping the Hematology & Oncology course did not significantly increase time investment for students during the course, and it also resulted in reduced cramming in the week preceding the end-of-course exam. Measurements of autonomy during the course and knowledge retention 10 months after the course were similar. Students initially reported higher self-efficacy scores at the end of the course, but this sense of competence over time decreased to levels similar to those reported by students learning in traditional education. Even though these long-term effects were not achieved, we do deem the found short term effects relevant in the context of mental health of (bio)medical students during their studies (e.g. IsHak et al., 2013).

In terms of practical implications, educators who are about to implement the flipped classroom approach should be well aware of the amount of time involved for both students and teachers. Students need to adapt their learning approach and study habits to benefit from the flipped classroom model. It seems that flipped classrooms have more obligations compared to traditional teaching approaches, as students need to be prepared for application of knowledge in the classroom. It has been shown that students need and want guidance when they are preparing for flipped classrooms (Wanner & Palmer, 2015), but it remains to be determined how to best organize this guidance and how educators can stimulate students' self-motivation and engagement with homework materials. Another question regards the longer-term effects of flipped classrooms, as future studies could determine whether medical students trained in flipped classrooms are better problem solvers in their future career (Chen et al., 2018), for instance during their clinical rotations.

For teachers, it is known that preparation of out-of-class materials and getting acquainted with the interactive, and in-depth teaching method is time consuming (Moffett, 2015; Snowden, 2012). Once the learning materials are created, they can be re-used in other classes (Moffett, 2015; Wagner et al., 2013). On the other hand, teachers might use existing learning materials, such as web-lectures and assignments used in Massive Open Online Courses (also known as Open Courseware). It might therefore be worthwhile to investigate teachers' perceptions of using Open Courseware. In addition, future studies could determine whether the hypothesis regarding the increased interactivity in flipped classrooms is true. Moreover, if asking questions and providing feedback to students remain feasible teacher activities in larger cohorts of students.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Other disclosures

None

Ethical approval

The Ethical Review Board of the Netherlands Association for Medical Education approved this study (file #387).

Disclaimer

None.

Declaration of interest

None.

Acknowledgements

The authors wish to thank the in-class observers, Paulien Postma and Karin Postma, for their time investment and critical review of classroom observations. In addition, the authors wish to thank Thijs van Houwelingen for his critical view in the audit procedure.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compedu.2019.05.002.

References

Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. *Computers & Education, 126*(July), 334–345. https://doi.org/10.1016/j.compedu.2018.07.021.

Anderson, T., Rourke, L., Garrison, D. R., & Archer, W. (2001). Assessing teaching presence in a computer conferencing context. *Journal of Asynchronous Learning Networks, 5*(2), 1–17.

Bergmann, J., & Sams, A. (2012). *Flip YOUR classroom reach every student in every class every day library of congress cataloging-in-publication data.* https://doi.org/10.1111/teth.12165.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning. *Science Education, 84*(6), 740. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=3771737&site=ehost-live&scope=site.

Bloom, B. S., Englehart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives, the classification of educational goals (Handbook I).* New York, NY: Longmans, Green, and Co.

Bonnes, S. L., Ratelle, J. T., Halvorsen, A. J., Carter, K. J., Hafdahl, L. T., Wang, A. T., … C.M (2017). Flipping the quality improvement classroom in residency education. *Academic Medicine, 92*(1), 101–107. https://doi.org/10.1097/ACM.0000000000001412.

Bouwmeester, R. A. M., de Kleijn, R. A. M., ten Cate, O. T. J., van Rijen, H. V. M., & Westerveld, H. E. (2016). How do medical students prepare for flipped classrooms? *Medical Science Educator, 26*(1), 53–60. https://doi.org/10.1007/s40670-015-0184-9.

Chen, F., Lui, A. M., & Martinelli, S. M. (2017). A systematic review of the effectiveness of flipped classrooms in medical education. *Medical Education, 51*(6), 585–597. https://doi.org/10.1111/medu.13272.

Chen, K. S., Monrouxe, L., Lu, Y. H., Jenq, C. C., Chang, Y. J., Chang, Y. C., et al. (2018). Academic outcomes of flipped classroom learning: A meta-analysis. *Medical Education, 52*(9), 910–924. https://doi.org/10.1111/medu.13616.

Chen, Y., Wang, Y., Kinshuk, & Chen, N. S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers & Education, 79*, 16–27. https://doi.org/10.1016/j.compedu.2014.07.004.

De Kleijn, R. A. M., Bouwmeester, R. A. M., Ritzen, M. M. J., Ramaekers, S. P. J., & Van Rijen, H. V. M. (2013). Students' motives for using online formative assessments when preparing for summative assessments. *Medical Teacher, 35*(12), 1–7. https://doi.org/10.3109/0142159X.2013.826794.

Deci, E. L., & Ryan, R. M. (1980). The empirical exploration of intrinsic motivational processes. *Advances in Experimental Social Psychology, 13*, 39–80 Academic Press.

Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01.

Deslauriers, L., Schelew, E., & Wieman, C. (2011). Improved learning in a large-enrollment physics class. *Science, 862*(May), 862–864. https://doi.org/10.1126/science.1201783.

Galway, L. P., Corbett, K. K., Takaro, T. K., Tairyan, K., & Frank, E. (2014). A novel integration of online and flipped classroom instructional models in public health higher education. *BMC Medical Education, 14*(1), 181. https://doi.org/10.1186/1472-6920-14-181.

Gilboy, M. B., Heinerichs, S., & Pazzaglia, G. (2015). Enhancing student engagement using the flipped classroom. *Journal of Nutrition Education and Behavior, 47*(1), 109–114. https://doi.org/10.1016/j.jneb.2014.08.008.

Hew, K. F., & Lo, C. K. (2018). Flipped classroom improves student learning in health professions education: A meta-analysis. *BMC Medical Education, 18*(1), 38. https://doi.org/10.1186/s12909-018-1144-z.

Hung, H. T. (2015). Flipping the classroom for English language learners to foster active learning. *Computer Assisted Language Learning, 28*(1), 81–96. https://doi.org/10.1080/09588221.2014.967701.

IsHak, W., Nikravesh, R., Lederer, S., Perry, R., Ogunyemi, D., & Bernstein, C. (2013). Burnout in medical students: A systematic review. *The Clinical Teacher, 10*(4), 242–245.

Jensen, J. L., Kummer, T. A., & Godoy, P. D. M. (2015). Improvements from a flipped classroom may simply be the fruits of active learning. *CBE-Life Sciences Education, 14*(2013), 1–12. https://doi.org/10.1187/10.1187/cbe.14-08-0129.

Khanova, J., Roth, M. T., Rodgers, J. E., & Mclaughlin, J. E. (2015). Student experiences across multiple flipped courses in a single curriculum. *Medical Education, 49*(10), 1038–1048. https://doi.org/10.1111/medu.12807.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory Into Practice, 41*(4), 212–218. https://doi.org/10.1207/s15430421tip4104_2.

Lai, C. L., & Hwang, G. J. (2016). A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. *Computers & Education, 100*, 126–140. https://doi.org/10.1016/j.compedu.2016.05.006.

Lo, C. K., & Hew, K. F. (2017). A critical review of flipped classroom challenges in K-12 education: Possible solutions and recommendations for future research. *Research and Practice in Technology Enhanced Learning, 12*(1), 4. https://doi.org/10.1186/s41039-016-0044-2.

McLaughlin, J. E., Roth, M. T., Glatt, D. M., Gharkholonarehe, N., Davidson, C. A., Griffin, L. M., … Mumper, R. J. (2014). The flipped classroom: A course redesign to foster learning and engagement in a health professions school. *Academic Medicine, 89*(2), 236–243. https://doi.org/10.1097/ACM.0000000000000086.

Moffett, J. (2015). Twelve tips for "flipping" the classroom. *Medical Teacher, 37*(4), 331–336. https://doi.org/10.3109/0142159X.2014.943710.

Morton, D. A., & Colbert-Getz, J. M. (2017). *Measuring the impact of the flipped anatomy classroom: The importance of categorizing an assessment by Bloom's taxonomy.* Anatomical Sciences Educationhttps://doi.org/10.1002/ase.1635.

Nunn, C. E. (1996). Discussion in the college classroom: Triangulating observational and survey results. *The Journal of Higher Education, 67*(3), 243–266. https://doi.org/10.2307/2943844.

Persky, A. M., & McLaughlin, J. E. (2017). The flipped classroom – from theory to practice in health professional education. *American Journal of Pharmaceutical Education, 81*(6)https://doi.org/10.5688/ajpe816118.

Porcaro, P. A., Jackson, D. E., McLaughlin, P. M., & O'Malley, C. J. (2016). Curriculum design of a flipped classroom to enhance haematology learning. *Journal of Science Education and Technology, 25*(3), 345–357. https://doi.org/10.1007/s10956-015-9599-8.

Prober, C. G., & Heath, C. (2012). Lecture Halls without lectures — a proposal for medical education. *New England Journal of Medicine, 366*(18), 1657–1659. https://doi.org/10.1056/NEJMp1202451.

Prober, C. G., & Khan, S. (2013). Medical education reimagined: A call to action. *Academic Medicine, 88*(10), 1407–1410. https://doi.org/10.1097/ACM.0b013e3182a368bd.

Sayeski, K. L., Hamilton-Jones, B., & Oh, S. (2015). The efficacy of IRIS STAR legacy modules under different instructional conditions. *Teacher Education and Special Education, 38*(4), 291–305. https://doi.org/10.1177/0888406415600770.

Sergis, S., Sampson, D. G., & Pelliccione, L. (2018). Investigating the impact of flipped classroom on students' learning experiences: A self-determination theory approach. *Computers in Human Behavior, 78*, 368–378. https://doi.org/10.1016/j.chb.2017.08.011.

Shimamoto, D. (2012). Implementing a flipped classroom: An instructional module. *Technology, colleges, and community worldwide online conference: Vol. 9*. Retrieved from http://scholarspace.manoa.hawaii.edu/handle/10125/22527.

Snowden, K. E. (2012). *Teacher perceptions of the flipped classroom: Using video lectures online to replace traditional*, *Vol. 70*University Of North Texashttps://doi.org/1522443.

Spangler, J. (2014). Costs related to a flipped classroom. *Academic Medicine, 89*(11), 1.

Street, S. E., Gilliland, K. O., McNeil, C., & Royal, K. (2015). The flipped classroom improved medical student performance and satisfaction in a pre-clinical physiology course. *Medical Science Educator, 25*(1), 35–43. https://doi.org/10.1007/s40670-014-0092-4.

Stuart, J., & Rutherford, R. J. D. (1978). Medical student concentration during lectures. *The Lancet, 312*(8088), 514–516. https://doi.org/10.1016/S0140-6736(78)92233-X.

Van Vliet, E. A., Winnips, J. C., & Brouwer, N. (2015). Flipped-class pedagogy enhances student metacognition and collaborative-learning strategies in higher education but effect does not persist. *CBE-Life Sciences Education, 14*(3), 1–10. https://doi.org/10.1187/cbe.14-09-0141.

van der Vleuten, C. P. M., & Driessen, E. W. (2014). What would happen to education if we take education evidence seriously? *Perspectives on Medical Education, 3*(3), 222–232. https://doi.org/10.1007/s40037-014-0129-9.

Volpe, R. J., DiPerna, J. C., Hintze, J. M., & Shapiro, E. S. (2005). Observing students in classroom settings: A review of seven coding schemes. *School Psychology Review, 34*(4), 454–474 School Psychology Review, 34(4), 451–453. Retrieved from http://www.researchgate.net/publication/232322340_Observing_students_in_classroom_settings_A_review_of_seven_coding_schemes._School_Psychology_Review_34(4)_454-474.

Wagner, D., Laforge, P., & Cripps, D. (2013). Lecture material retention: A first trial report on flipped classroom strategies in electronic systems engineering at the university of Regina. *Proceedings of the Canadian Engineering Education Association (CEEA), 1–5*https://doi.org/10.24908/pceea.v0i0.4804.

Wanner, T., & Palmer, E. (2015). Personalising learning: Exploring student and teacher perceptions about flexible learning and assessment in a flipped university course. *Computers & Education, 88*, 354–369. https://doi.org/10.1016/j.compedu.2015.07.008.

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of Personality and Social Psychology*. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed4&NEWS=N&AN=8636897.

Wittich, C. M., Agrawal, A., Wang, A. T., Halvorsen, A. J., Mandrekar, J. N., Chaudhry, S., ... Beckman, T. J. (2017). Flipped classrooms in graduate medical education: A national survey of residency program directors. *Academic Medicine, 93*(3), 471–477. https://doi.org/10.1097/ACM.0000000000001776.