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Student Learning Performance and Satisfaction With a Flipped Classroom in Undergraduate Dental Pharmacology Education

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ABSTRACT

Introduction: The flipped classroom (FC) model of blended learning has become more feasible with the advancement of digital technology platforms. Monitoring a FC approach in curriculum delivery provides an opportunity to evaluate its impact on student exam outcomes and satisfaction. Presented here are examination performances and learning experiences in undergraduate dental students taking pharmacological course material using a FC approach compared to that of a traditional classroom (TC) model.

Method: Ninety-seven students experiencing a FC delivery are compared to 129 students taking a TC approach over 2 academic years. Course lecture topics, scheduling, and assessment are consistent across both modes of delivery. At the end of each academic year, an anonymous student survey with a closed-end question was conducted to gain student feedback regarding course satisfaction.

Results: The FC positively improved student examination performances compared to the TC approach with a 7% increase in the percentage mean exam grade and a 15% increase in the number of students obtaining exam grades greater than 50%. An increase in the proportion of students achieving higher grades overall is seen in the FC versus the TC approach from the frequency distribution of exam results. The students also rated the FC more positively in the feedback satisfaction compared to the TC student cohort.

Conclusion: In summary, the student exam grades and feedback here indicate that the FC has a positive impact on student outcomes and experience compared to the TC approach. These findings provide evidence to dental pharmacological educators that an FC curriculum delivery can lead to an improvement in student performances in this subject area.

1 | Introduction

The flipped classroom (FC) is a teaching approach that is moving away from the traditional classroom (TC) model of lecture-based instruction [1] and is being implemented more across higher education institutions since disruptions occurred during

the COVID-19 pandemic [2, 3]. The TC approach involves the in-class didactic lecture where students are usually presented with new content for the first time [4]. The TC learning environment is instructor-focused and students are passive listeners with little student participation and active learning [5]. This form of delivery reduces student participation in class and has been shown

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to be less effective compared to more active FC learning environments [6–8].

In a FC, students are introduced to the subject matter before in-class time through the use of multimedia resources [9] as well as other reading material. Class time is then used for active learning activities such as discussions, problem-solving, group work, and hands-on exercises [10]. The pre-class activities allow students to engage with learning material independently before coming to class and typically involve watching video lectures, reading assigned texts, or completing online module problems and case studies. During the in-classroom phase, more time is allowed for instructor-student interaction, peer group discussions, and the application of knowledge [11]. The role of the instructor in the FC shifts from delivering content in lectures to guiding students' understanding, providing feedback, and facilitating deeper exploration of concepts during class time [12]. The FC approach emphasizes active engagement and student-centered learning and is now implemented across many health and medical science curricula [13–16]. Students have the opportunity to take more responsibility for their learning by actively participating in discussions, asking questions, and collaborating with peers. The flexibility of the FC model also allows for students to engage with online content at a time suitable for them [17]. Technology plays a central role in the FC model, enabling students to access learning materials online and facilitating communication and collaboration both inside and outside the classroom [18].

The landscape of higher education teaching delivery across medical and dental curricula is changing, as described above, from a TC to a FC approach with the introduction of various digital multimedia platforms available to students. As no defined structure to the FC exists, educators are free to implement models related to their area of study and subject content when moving away from the TC approach. It is, therefore, critical to evaluate the learning effects when such models are implemented. During the evaluation process of the FC model, it is necessary to understand its potential benefits to student performance outcomes, such as exam grades, but also to understand the students' perception of the learning experience. In order to address this, we compared the FC to TC approach in the delivery of pharmacological course content to undergraduate dental students, evaluating both students' learning performances and course satisfaction. The primary aim of this study was to assess the impact of the introduction of a FC model in replacement of a TC approach to deliver pharmacology content to dental students' learning experience. Specifically, the assessment of student performance focused on a review of exam results related to pharmacological content to measure the impact of a change from a TC to a FC approach in curriculum delivery. This was followed up by an anonymous student survey taken at the end of a continuous FC or TC teaching strategy to measure student perceptions.

2 | Methods

2.1 | Module Organization and Delivery

A flipped classroom (FC) and traditional classroom (TC) model in the delivery of a pharmacology curriculum to undergraduate dental science students is described here. The

FC design involves a hybrid asynchronous teaching approach compared to the TC synchronous in-class lecture-based delivery. The course lecture topics, scheduling, and faculty members involved in teaching are consistent across both modes of delivery, which run over 2 semesters in year 3 of the curriculum. The students participating in either the FC or TC delivery modes were dental science students enrolled in the third year of a 5-year degree program. The FC delivery mode was implemented over two academic years, starting in September 2021 and 2022, with a sample size of $n = 97$ students. The TC delivery mode, on the other hand, was implemented in September 2017 and 2018, with a sample size of $n = 129$ students. As a result, the two cohorts of students were distinct, with no student experiencing both delivery modes. There was no prior selection process for assignment to either mode; all students registered in year three of the degree program during the specified years were included. Excluded here are academic years beginning 2019 and 2020 due to COVID-19 pandemic disruptions in the examination evaluation format.

2.2 | Teaching Methods

All content was presented sequentially across both methods of delivery. The FC approach consisted primarily of voiceover lecture slides recorded using Panopto (Panopto Inc. Pittsburgh, PA 15212) video platform with reflective questions embedded in the recording for students to review and answer as the recording progressed in real time. Each recorded lecture topic was, on average, 40 min and was released weekly to the students via the virtual learning platform, Blackboard Learn, over 2 semesters. Lecture notes, textbook chapter reading material, and dental clinical case scenarios with reflective questions accompanied each lecture recording for student consideration and pre-class study activities. Live in-person classes with the course lecturer were scheduled every 3 weeks throughout the term for review and reflection of released content. Here, students discussed and reflected on prior released content, with discussions focusing on pre-class activities. At the beginning of semester 1, the course lecturer presented an in-person introduction to students describing the FC, its layout, pre-class activities, location of content as well as student expectations and engagement. The traditional in-person classroom model consisted of in-class one-hour lecture time slots, delivered using PowerPoint presentations followed by a wrap-up question and answer time. In the traditional classroom, no pre-class activities were required by students in preparation for class; instead, lecture notes and textbook chapter reading material were released and referred to following each live lecture for students to support study activities post in-class time.

2.3 | Student Learning Outcomes

Written final semester assessment data related to the pharmacological course content included an extended matching multiple-choice style question and a short answer written question. The assessment format was the same across both methods of content delivery. The exam questions were not identical for both groups, though they were similar in style. As a result, each group received a distinct set of questions,

which minimized the potential for bias from prior exposure. The process for creating these questions follows the school's standardized protocol. Instructors submit the exam questions along with sample answer schemes, which are then reviewed internally by the undergraduate course director and other academic staff teaching in the dental program for that year. Additionally, external examiners assess the questions for appropriateness and consistency regarding content, as well as difficulty and alignment with the curriculum's learning outcomes. Anonymized unadjusted percentage examination results related to pharmacological course content questions were averaged for each student, with an overall average across each type of delivery method taken for comparison. Exam grade data were tested for normality using the D'Agostino-Pearson normality test, taking a p value greater than 0.05 as normally distributed. An unpaired students t -test was used to measure any significant differences. Individual student exam results were also ranked to see the number of students obtaining results above or below the 50% pass grade. Frequency distribution histogram plots showing percentage frequency of students obtaining specified grades between 0% and 100% using a 5% incremental grade range for each method of delivery were also compared. Here, the minimum, median, maximum, as well as 25th and 75th percentile grade values were used for comparison in learning performances.

2.4 | Student Feedback

Feedback data was collected using Qualtrics software (Provo, UT) at the end of each academic year. Students were given a Qualtrics link to an anonymous feedback survey, and time in class was allocated to complete it. A trichotomous closed-end question scale was presented to students to score student satisfaction with the module as: good, satisfactory, or non-satisfactory. Survey responses were averaged for each score across each method of delivery and compared. The student response number of 78.34% (76/97) for the FC versus 62.79% (81/129) for TC was included.

2.5 | Statistical Analysis

Graphical data and statistical analyzes were conducted using Excel and GraphPad Prism (version 10.0, GraphPad Software, San Diego, CA, USA). Data for comparison are presented as mean $\pm$ SD and tested for normality using the D'Agostino-Pearson test. Normally distributed data were further analyzed using an unpaired two-tailed t -test and significant differences taken as $*p \leq 0.05$, $**p \leq 0.01$, $***p \leq 0.001$. Chi-square test was used to test significant differences in the response satisfaction rating when comparing the 2 teaching approaches.

3 | Results

3.1 | Student Examination Outcomes

Presented here is student examination performance in the subject of pharmacology using a flipped classroom (FC) pedagogy model compared to the traditional classroom (TC). In total,

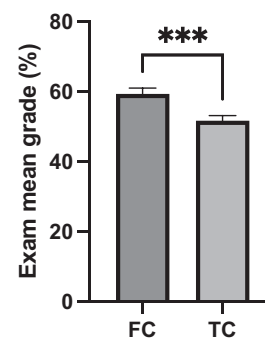


FIGURE 1 | Percentage pharmacological mean exam grades $\pm$ SD for students following a flipped classroom (FC) $n = 97$ versus a traditional classroom (TC) $n = 129$ method of course content delivery. Statistical analysis of significance between both methods determined using an unpaired students t -test $***p < 0.001$.

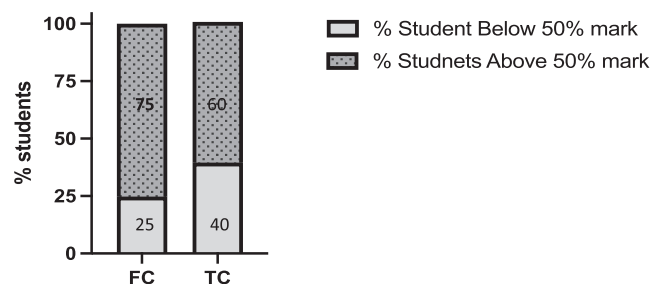


FIGURE 2 | Percentage of students obtaining pharmacological assessment exam grades below 50% and above 50% following a flipped classroom (FC) or traditional classroom (TC) method of course content delivery.

97 students were enrolled in the FC versus 129 students in the TC approach. Student examination performance is shown in Figure 1 with the percentage mean $\pm$ SD exam grade in the FC ($59.38\% \pm 1.62\%$) significantly greater than that of the TC ($51.70\% \pm 1.45\%$) ($p < 0.001$). The FC also positively improved student pass rate ($> 50\%$) performance as shown in Figure 2 where 75% of the students taking an FC approach obtained an exam grade greater than 50% compared to 60% of students in the TC approach. Improvement in exam grades is also shown in Figure 2 with fewer students in the FC (25% of students) obtaining a grade less than 50% compared to students in the TC (40% of students) approach.

A closer look at the frequency distribution of exam grades for all students is shown in Figure 3. The fitted bell curves for the distribution of results for both FC (Figure 3a) and TC (Figure 3b) display relatively equal normal distributions, and this was also calculated with the D'Agostino-Pearson normality test ($p = 0.2548$ FC, $p = 0.4885$ TC). The overall distribution of results was improved in the FC approach compared to the TC. This was seen in the most frequent grade in the FC occurring between 70% and 75% versus 50% and 55% being the most frequent grade in the TC approach. A minimum exam grade of 5% is seen for the TC, which was improved in the FC cohort of students, where the minimum exam grade was above 20%. A rightward shift in the fitted bell curve is seen for the FC exam grades (Figure 3a) as evident from the higher percentile grade values (25th percentile grade value of 48.75, median percentile grade value of 60, and

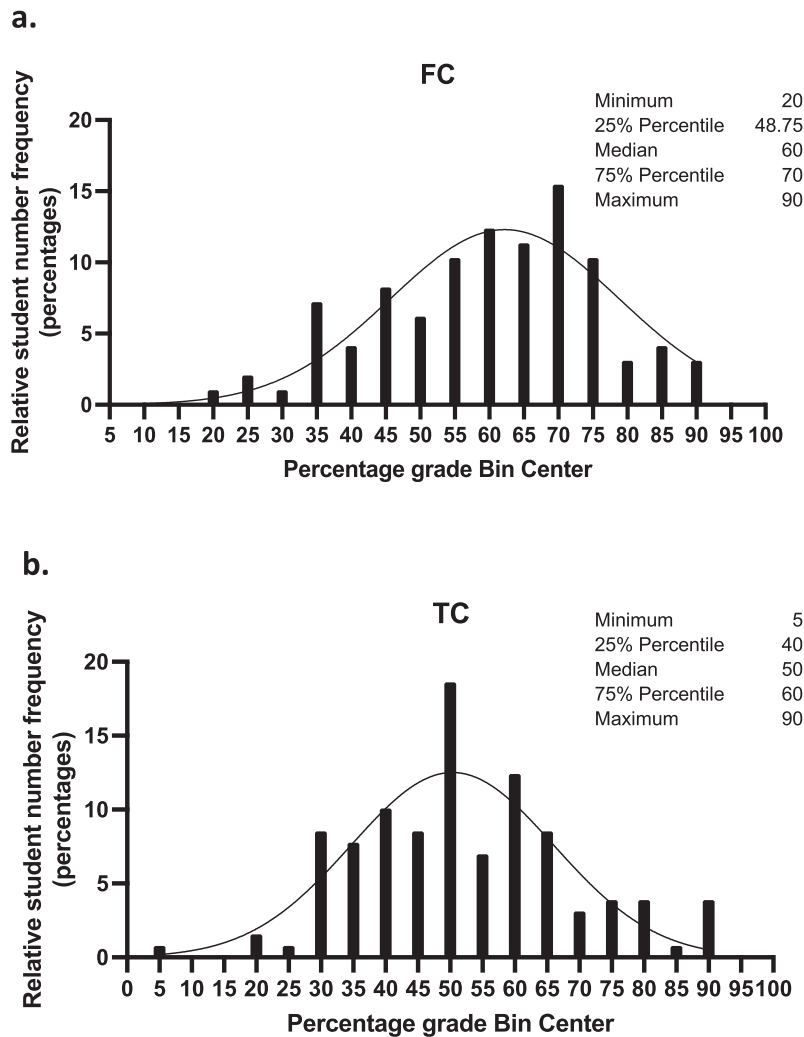


FIGURE 3 | Frequency distribution of pharmacological exam grades obtained by students taking (a) flipped classroom (FC) versus (b) traditional classroom (TC) method of course content delivery. Exam results ranging from 0% to 100% are plotted with each bar width representing a percentage grade range in increments of 5% versus each bar height representing the frequency of students attaining results for each grade range. Grade values of minimum, mean, maximum, and percentiles (25th and 75th) are displayed on each graph.

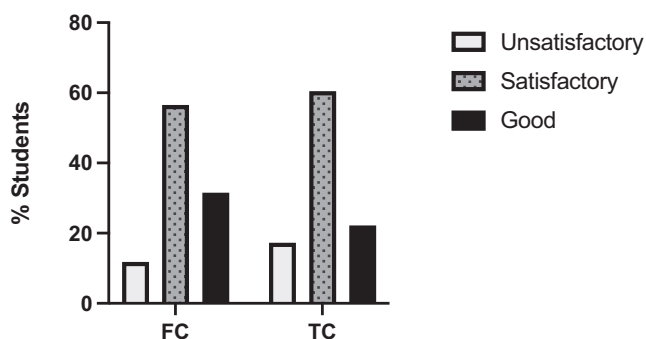


FIGURE 4 | Student feedback based on percentage of student satisfaction ratings from those taking a flipped classroom (FC) versus a traditional classroom (TC) approach. Presented here is the percentage of students rating the course as either unsatisfactory, satisfactory, or good.

75th percentile grade value of 70) in FC compared to lower percentile grade values (25th percentile grade value of 40, median percentile grade value of 50, and 75th percentile grade value of 60) in the TC distribution (Figure 3b). This rightward shift in the

FC curve fitting indicates an increase in the proportion of students achieving higher grades in the FC versus the TC approach overall across all grades. Altogether, the FC approach shows an overall improvement in student examination performances compared to the TC approach.

3.2 | Student Feedback

The student feedback on course content and experience from the anonymous student survey was conducted for academic years beginning September 2017 and 2018 for TC and September 2021 and 2022 for FC, as shown here in Figure 4. The overall response rate to the student survey was 78.34% (76/97) for the FC versus 62.79% (81/129) for the TC. In general, students rated the course content and experience 6% higher in the FC (88% satisfactory or above, raw count) compared to the TC (82% satisfactory or above). This was reflected in the unsatisfactory rating, with the TC (17.28%) having a 6% higher score rate compared to the FC (11.82%). This improvement in overall student satisfaction was also seen in the good rating, with 9% higher score rates in the FC

(31.5%) compared to the TC (22.2%) cohort. Despite this, a Chi-square test of raw count responses did not show a significant difference ($p = 0.3365$) in the response satisfaction ratings when comparing the 2 teaching approaches. Altogether, the students had an overall tendency to rate the FC higher compared to the TC student cohort in the satisfactory scaling presented here.

4 | Discussion

The idea and model of the FC was first introduced in the 1990s by Harvard Professor Eric Mazur, where he provided material for students to prepare and reflect on before class. This approach allowed for and encouraged deeper cognitive thinking via peer interaction and instructor challenge during in-class time [19]. Many FC approaches have since been described in the educational literature, with a common theme that students have access to some form of course material before in-class time [20, 21]. The FC teaching approaches today are further facilitated with the advancement and development of digital technology platforms specifically designed for educational institutions [9] and there is now growing evidence on the beneficial effects of the FC model in dental [20, 22] and medical [4, 7] educational programs.

Here we introduced a FC model to our pharmacology undergraduate dental education programme and compared its impact to a TC delivery approach. The mean examination result was significantly better in the FC cohort end-of-year assessment in pharmacology content compared to the TC cohort ($p < 0.001$). The learning effect of students with the FC approach was better overall with an increase in the frequency of higher grades achieved compared to that of students taking the traditional teaching approach. The FC approach also received more positive feedback from students compared to the traditional instructor-led lecture model. These findings are consistent with FC approaches applied to other areas of medical and dental educational programs [7, 8, 12, 20]. A limitation of the data presented here is that, due to the retrospective and anonymous nature of the study design, an analysis of gender differences in student performance or experiences was not possible. Conducting such an analysis could have provided deeper insights into how different delivery modes impact students based on gender, as well as other demographic cohorts.

The overall improved exam results and positive experience from students are likely reflective of the specific aspects of FC teaching, for example, the increased student–instructor interaction and discussion around case-based content introduced in the FC to foster the development of higher-order cognitive skills and application of knowledge [6, 8, 11, 13]. The self-directed, independent pre-session time encourages students to take personal responsibility for their own education. This allows students to build a knowledge base before the collaborative classroom sessions, empowering students in the learning process. In general, students rated the course content and experience higher (satisfactory or above) in the FC compared to the TC, despite a Chi-square test of raw count responses not showing a significant difference ($p = 0.3365$) here. This would argue for a mixture of the traditional and flipped classroom models, with some students valuing listening to the live in-person lecture [23]. The student satisfaction rating is based on one type of student experience for each teaching method and is a limitation for a true

comparison of the effect here. To truly compare individual students' experiences for each teaching method, a mixed exposure for each student to each teaching approach would provide for a more informative comparison.

The full effect of the FC educational benefits will only be realized if students engage with the content before class. To help with this, scheduling and timed release of content are important to avoid information overload and overburdening students' workloads. An ideal approach may also require the use of multiple tools and strategies that accommodate a variety of learning styles while meeting the learning objectives of the curriculum. In addition, implementing other forms of blended learning, such as extending the in-class experience by encouraging students to engage with supplementary online materials like videos and podcasts related to lecture topics—may better address individual student needs. These resources serve as additional learning supports without replacing face-to-face instruction, as is the case with the flipped classroom model described here. Successful implementation of the FC approach requires careful consideration of factors such as curriculum design, the timing of content delivery, faculty development, and the willingness to adapt teaching methods. Additionally, investment in technological infrastructure, managing appropriate staff-to-student ratios during discussion sessions, and ensuring student readiness and active participation are all essential FC components [24, 25]. Both student self-directed learning outside the classroom and in-class instructor interactions and discussions are needed to see the full benefits of the enriched environment that can be provided by the FC learning experience. In addition to this, designing approaches to teaching and learning should provide for equality, diversity, and inclusion in the learning environment that recognizes individual differences in the learning process that meet the needs of all students effectively. Altogether, the positive outcome in learning performances and student experiences the FC model showed in our approach here to the study of pharmacology to undergraduate dental science students suggests the positive impact and utility the FC approach can have.

5 | Conclusion

The findings here provide evidence to dental pharmacological educators that a FC curriculum delivery can lead to an improvement overall in student learning performance and satisfaction in this subject area. Despite this and the overwhelming literature that supports a role for the FC-based approach to teaching over the traditional teaching model, it is important that each institution and discipline introducing such changes evaluate its own performance on an ongoing basis.

Author Contributions

M.L. has contributed to the conception, design, acquisition of data, data analysis, and interpretation of data. M.L. and S.G. both contributed to drafting the manuscript and interpretation of data.

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Ethics Statement

The Research Ethics Committee in the School of Dental Science, Trinity College Dublin reviewed and approved the study design.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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