An Innovative Flipped Class Intervention to Improve Dose Calculation Skills Of Phase I Medical Students: A Preliminary Study

Biswadeep Das\textsuperscript{a*}, Chayna Sarkar\textsuperscript{b}

\textsuperscript{a} Dr. Division of Pathology, School of Medicine, International Medical University(IMU), No. 126, Jalan Jalil Perkasa 19, Bukit Jalil, 57000 Kuala Lumpur, Malaysia.

\textsuperscript{b} Dr. Department of Pharmacology, North Eastern Indira Gandhi Regional Institute of Health & Medical Sciences(NEIGRIHMS), Mawdiangdiang, Shillong-793018, Meghalaya, India.

Abstract

Numeracy is important in the practice of medicine. Few studies have addressed the ability of medical students to perform arithmetical calculations required to identify the correct mass or volume of a drug in solution. This study assessed the ability of Phase I medical students to effectively recall and use knowledge of systems and measures for calculation of strengths of drugs in solution before and after a Systems of Measure & Dosage Calculation Flipped Class Session(SMDC-FCS). Those participating voluntarily were present during the pre- & post- SMDC-FCS to answer selected questions in succession under timed conditions. The questions were devised to test knowledge of medications used across multiple specialities. Our study data indicates that our medical students are not informally picking up requisite knowledge and skills during the MBBS course. A SMDC-FCS intervention improved medical student performance of dose calculations.

1. Introduction

Accurate calculation of drug doses must be performed by health-care professionals (Oldridge et al, 2004). An adverse
Drug event (ADE) is known to occur during 0.7-6.5% of hospital admissions in the US, 1.5% in the UK, and 1.8% in Australia (Leape et al, 1991; Bates et al, 1995; Neale et al, 2001; Wilson et al, 1995). 15% of hospital ADE’s and 76% of ADE’s leading to admission were judged preventable. Drug administration frequency (contributing to ADE’s) have been documented to be as high as 19% of all drug administration episodes, and 17% of these were dose errors (Allan & Barker, 1990; Dean et al, 2000; Barker et al, 2002). The inherent knowledge of systems of measure and the contribution of different means of expressing drug concentrations in solution, have been rarely assessed, although medical students and even hospital doctors are known to struggle with drug dose calculations (Rolfe & Harper, 1995). When a drug in solution is administered, precise volumes need to be estimated. An understanding of the multiple means of expressing the concentration of drugs in solution is critically important in order to execute the stepwise calculations (Sarkar & Das, 2007). The various ways of expressing drug concentrations in solutions, as ratios (e.g., 1 in 1000), or percentages or mass per unit volume (e.g., milligrams or millimoles per millilitre), are a potential cause of confusion that may contribute to dose errors (Stefanou & Siderov, 2001). The metric system is based on thousands whilst percentages deal with hundreds, even these simple means of expressing drug concentrations can be a potential source of confusion. Calculating the safe volume of drug mixtures or rates of drug infusions are even more difficult, like, the mixture of 1% lidocaine and 1 in 200 000 epinephrine that is often infiltrated surgically (Lawrence, 1996).

Medical education literature documents that concentration of students begins to falter after 10-15 minutes (Stuart & Ruthenberg, 1978) and hence, maintaining student attention during didactic lectures is a significantly difficult challenge (Bligh, 2000). In a flipped class, students study the topic independently and then spend the class time solving problems, applying the concepts to case studies or doing practical application activities. Instructors act as tutor or coach to help students in areas where they have trouble in application of concepts (Alvarez, 2011). Teachers employ assessment methodologies like interactive quizzes or projects to check student perusal of the home video and to quantify student comprehension and application of concepts (Barseghian, 2011). Flipped classes enable instructors to spend extended time with students and facilitate them towards creation of higher level application projects (Tucker, 2012) which culminates in an increased learning (Mazur, 1991).

Poll Everywhere is an Audience Response System (ARS). It is also termed as a personal response system or in education circles, as a student polling system (clickers). Utilising an ARS, a presenter or instructor projects questions on a screen to which the audience responds with some kind of a remote device. Responses are then collected and displayed in a graphical method in real-time on the screen. ARS caters for increased interactivity by promoting a two way flow of communication between the speaker and the audience. Hence, ARSs have been found to be of particular benefit when working with large groups where communication is challenging or with groups whose members might not otherwise fully participate. Research published over the last decade indicates that classroom use of an ARS can have a significant, positive impact on student learning (Kay & LeSage, 2009). Poll Everywhere, unveiled in 2007, offers a simple setup by harnessing an internet connection, a Web browser and smart devices. No other extra hardware or software is required for this.

In our study, we intended to i) assess the baseline knowledge of students on systems of measure and drug dose calculation skills and to ii) determine whether a combination of flipped classroom activity and Poll Everywhere was successful in engaging attention, facilitating participation and learning among three cohorts of undergraduate Medicine students for delivering the Systems of Measure & Dosage Calculation Block in a university setting.

2. Materials and Methods

The Systems of Measure & Dosage Calculation Block under the Bachelor of Medicine & Bachelor of Surgery (MBBS) programme for semester 2, 3 & 4 undergraduate medical students was designed to provide background knowledge and development of numeracy skills on systems of measure and drug dose calculations. This module was organized into components which included a general introduction to the systems of measures, concepts on interconversion between different units, concepts on interconversion between metric units, weight to percentage conversions and vice versa, drug dosage calculations using ratio (rainbow), proportion, formula, and dimensional analysis methods, solved representative examples and useful formulas for drug dose calculation problems and helpful resource materials and websites.

2.1 Study Design:

Observations were made at three time points before and after an intervention (i.e., flipped classroom activity) and during the flipped classroom session and the participants acted as their own controls.
2.2 Setting:

This study was conducted in the Division of Pathology, School of Medicine at the International Medical University (IMU), Bukit Jalil Campus in Kuala Lumpur, Malaysia.

2.3 Study Period:

This study was conducted during a period of two weeks from 1st April 2014 to 15th April 2014. Medical students of semesters 2, 3, and 4 were subjected to a baseline quiz on April 1, 2014 (pre-test). Four i-lectures and pre-reading materials were made available for the participants on the e-learning portal of the International Medical University (IMU) two weeks prior to the flipped classroom activity. The flipped classroom activity was conducted on 15th April 2014 in the form of a Quiz and discussion. This was followed by an immediate feedback and debriefing session. The data collection on end of semester examination result was carried out on 30th April 2014 (post-test).

2.4 Inclusion Criteria:

All the 362 undergraduate students of Medicine from Semesters 2, 3, & 4, who gave informed written consent to participate in this study, were included. They were all invited to participate in a baseline Quiz and respond to a Quiz & Feedback questionnaire at the end of the flipped classroom activity.

2.5 Exclusion Criteria:

Eligible students who were absent on the day of the flipped classroom activity were excluded from this study.

2.6 Ethical Considerations:

Approval for the present study was obtained from the Division of Pathology, School of Medicine at the International Medical University (IMU), Kuala Lumpur, Malaysia. Informed written consent was obtained from every participant prior to the inception of the study. The information obtained during the data collection was strictly kept confidential. In order to maintain anonymity, a random code number was issued to each participant of this study while responding to the quiz and feedback questionnaire.

2.7 Study Instruments:

The ‘Poll Everywhere’ is web-based software for analysing instant poll responses from the audience by using smart devices like smart phone, tablet, computers or laptops. It is an interactive Audience Response System (ARS) which can be used in a flipped classroom activity. The instructor can assess the responses of the participants instantly during an interactive session and provide valuable feedback on spot to the respondents. For ‘Poll Everywhere’, the minimum required bandwidth of Local Area Network (LAN) is 4Mbps for downloading and 30Mbps for uploading. However, for Wifi internet connection, the minimum required bandwidth for downloading is 9Mbps and 17Mbps for uploading. Ten quiz questions, covering the learning outcomes of the flipped classroom activity, were included in this ‘Poll Everywhere’ software for seeking participant responses.

A feedback questionnaire on the flipped classroom activity was adapted from a validated questionnaire developed by Pierce & Fox(2012). This questionnaire was modified and revalidated during a pilot study to suit our needs. The final feedback questionnaire included the following items:

1. Pre-reading materials (i-Lecture/others) were available on e-learning portal before the flipped classroom activity.
2. Adequate time was provided to spend on the pre-reading materials (i-Lecture/additional references etc.) before the flipped classroom activity.
3. Pre-reading materials were relevant for the flipped classroom activity.
4. The classroom arrangements (positioning of the chairs for group activity, audio-visual facilities etc.) were conducive for the flipped classroom activity.
5. The activities during flipped classroom session increased my understanding of the key concepts.
6. The flipped classroom session inspired me to pursue further learning for the module.
7. More lectures should be conducted in the flipped classroom mode.
8. Instructor was able to engage me in the flipped classroom activity.
9. Instructor was able to provide clarification on difficult concepts during the flipped classroom activity.
10. Instructor was able to expand on i-lectures and pre-reading materials during the flipped classroom activity.

2.8 Data Collection Procedure:

The Systems of Measure & Dosage Calculation Block contained 4 hours of lecture, 2 hours of guided reading and 3 hours of computer assisted learning and power-point presentation. The Systems of Measure & Dosage Calculation-Flipped Classroom Session(SMDC-FCS) was planned after a series of four lectures covering the same content area as the learning outcomes of the flipped classroom activity.

A pilot study was conducted involving the same three cohort of students on another module one month before the main study. The feasibility and time management of reviewing four i-lectures and pre-reading materials along with the conduction of flipped classroom activity were assessed. An item analysis along with test-retest validity and intra-observer reliability (Cronbach’s alpha) of the feedback questionnaire were also assessed during this pilot study. The feedback questionnaire was further refined with the help of two content experts and an English language professional.

Four i-lectures and pre-reading materials related to the learning outcomes of flipped classroom activity were made available in the e-learning portal for access to the students two weeks before the flipped classroom activity. All the learning outcomes from the flipped classroom activity were created from the four designated i-lectures and pre-reading materials.

The flipped classroom activity was conducted for 50 minutes in the form of an instructor-created quiz with five questions. Some audio and video presentations were used as indirect cues to the quiz questions which catered to the learning outcomes of the flipped classroom activity. The evaluation of quiz (pre-test) during flipped classroom activity through ‘Poll Everywhere’ was conducted by using these five questions.

The students were instructed to bring their smartphones, tablets or laptops to the flipped classroom for interactive participation. Flipped classroom activity was conducted in the form of an interactive quiz session by using “Poll Everywhere” for web-based participant interaction. Though internet connection was provided, the participants were not given access to the four designated i-lectures and pre-reading materials during the flipped classroom activity while responding to the quiz. They were also not allowed to carry hand-outs of the designated i-lectures and pre-reading materials during the flipped classroom activity.

The instructor revealed one quiz question on ‘Poll Everywhere’ at a time and requested the participants to select their one best response from the given five options. Five minutes was allocated for the participants to register their responses online at ‘Poll Everywhere’ through their smart devices. After all the responses were captured the poll froze and the poll-result was displayed on the screen. Since, the quiz was conducted before any discussion, the poll responses were considered as pre-test in this study. The instructor discussed each of the options in brief and engaged the participants in debate for the next three minutes. The students were guided by the instructor to identify the correct answer for each quiz question only after evaluating all the five options. This procedure was repeated for all the five quiz questions. Five minutes were allocated for poll and discussion on each quiz question during the flipped classroom activity. Hence, it was possible to conduct the entire flipped classroom activity within 50 minutes. Since, the answer for each quiz question was revealed at the end of discussion, an immediate post-test on the same questions was not deemed necessary.

A feedback questionnaire was administered to the participants for ten minutes after the flipped classroom activity. This was followed by a debriefing session for five minutes.

The effectiveness of flipped classroom activity was also assessed by comparing the performance of participants on the end of semester examination questions related to the baseline(pre-test) and flipped classroom activity. The end of semester examination was conducted 2 weeks after the formative assessment. It included 5 questions from the Systems of Measure & Dosage Calculation Block encompassing the baseline(pre-test) and flipped classroom activity. All the questions were vetted by the Medicine experts and their difficulty levels were matched with the quiz questions administered at baseline(pre-test) and during the flipped classroom activity.
2.9 Data Analysis:

The data collected were tabulated and analysed by using the EPI-INFO version 5.0 for Windows and SPSS(Statistical Package for Social Sciences) version 17.0. Data regarding mean test scores were analysed using Kruskal Wallis non-parametric tests. Other results were expressed in terms of proportion, median, and interquartile range(IQR). The strengths of association were computed by using the Odds Ratio(OR), Relative Risk(RR), and their 95% Confidence Intervals. In this study, a \( p \)-value <0.05 was considered as statistically significant.

3. Results

362 medical students participated in the study out of which 122 students (33.7%) were from the second semester, 130 students (35.91%) were from third semester, and 110 students (30.38%) were from the fourth-semester of the MBBS course. The results are summarized in Table 1.

Table 1. Results of assessment of knowledge of systems of measures used in dispensing pharmacy and calculation of doses of drugs in solution in the context of student seniority

| Student seniority (Semester) | Second(n=122) | Third(n=130) | Fourth(n=110) |
|------------------------------|--------------|--------------|---------------|
|                              | Pre | Post | Pre | Post | Pre | Post |
| Question 1                   |     |      |     |      |     |      |
| No. answering correctly      | 0   | 108  | 0   | 112  | 0   | 99   |
| No. attempting question      | 120 | 122  | 128 | 128  | 108 | 105  |
| % answering correctly        | 0   | 88.52 | 0   | 87.5 | 0   | 94.29 |
| Question 2a                  |     |      |     |      |     |      |
| No. answering correctly      | 81  | 120  | 93  | 114  | 68  | 101  |
| No. attempting question      | 118 | 122  | 126 | 129  | 108 | 110  |
| % answering correctly        | 68.64 | 98.36 | 73.8 | 88.37 | 62.96 | 91.81 |
| Question 2b                  |     |      |     |      |     |      |
| No. answering correctly      | 81  | 122  | 90  | 130  | 93  | 108  |
| No. attempting question      | 118 | 122  | 130 | 130  | 110 | 110  |
| % answering correctly        | 68.64 | 100  | 69.23 | 100  | 84.54 | 98.18 |
| Question 3                   |     |      |     |      |     |      |
| No. answering correctly      | 78  | 105  | 83  | 103  | 76  | 98   |
| No. attempting question      | 121 | 120  | 118 | 125  | 107 | 110  |
| % answering correctly        | 64.46 | 87.50 | 70.33 | 82.4 | 71.02 | 89.09 |
| Question 4                   |     |      |     |      |     |      |
| No. answering correctly      | 67  | 96   | 78  | 109  | 57  | 87   |
| No. attempting question      | 120 | 122  | 128 | 127  | 108 | 110  |
| % answering correctly        | 55.83 | 78.68 | 60.93 | 85.82 | 52.77 | 79.09 |
| Question 5                   |     |      |     |      |     |      |
| No. answering correctly      | 45  | 93   | 52  | 99   | 44  | 83   |
| No. attempting question      | 120 | 121  | 127 | 124  | 106 | 108  |
| % answering correctly        | 37.5 | 76.85 | 40.94 | 79.83 | 41.51 | 76.85 |

Some students failed to attempt every question. The overall pre-test & post-test mean scores for all students was 2.02 & 4.03 out of 5.00 (corresponding to 40.4% & 80.6%). The mean pre-test score deteriorated with increasing student seniority; second semester students scored 2.30 (n=122; range 0-4; SE 0.14), third semester students scored 2.01 (n=130; range 0-4; SE 0.12), and fourth semester students scored 1.83 (n=110; range 0-3.5; SE 0.28). The mean
post-test scores improved over the pre-test scores; second semester students scored 4.20 (n=122; range 0-5; SE 0.14), third semester students scored 4.22 (n=130; range 0-5; SE 0.12), and fourth semester students scored 4.25 (n=110; range 0-5; SE 0.18).

The overall intra-observer reliability from Cronbach’s Alpha was found to be 0.852. The intra-observer reliability ranged between 0.755 and 0.845 for item deletion in Cronbach’s Alpha analysis. Since, none of the Cronbach’s Alpha values exceeded 0.852 in item deletion; all the ten items of feedback questionnaire, used to capture the perception of participants on the flipped classroom activity, were included in the final analysis.

As far as the central tendencies and dispersions of responses on individual items in feedback questionnaire the analysis revealed that majority agreed (3) or strongly agreed (4) on the following items: (a) i-lectures and pre-reading materials were available on e-learning portal before the flipped classroom activity, (b) i-lectures and pre-reading materials were relevant for the flipped classroom activity, (c) physical arrangements were conducive for flipped class room activity, (d) flipped classroom activity had increased the understanding of topics and pursue further learning for the module, (e) instructor was able to actively engage the students during the flipped classroom activity, (f) instructor was able to provide clarification on difficult concepts and (g) instructor was able to expand on the i-lectures and pre-reading materials. However, the central tendency was found to be 3(agree) with IQR ranging between 2(neutral) and 4(strongly agree) for adequate time spent by the students on i-lectures and pre-reading materials. The results indicated that most of items favoured the flipped class room activity which was considered as an effective teaching-learning tool by the participants and majority recommended that more lectures should be conducted in the flipped classroom mode.

Though all the students agreed that i-lectures and pre-reading materials were available on e-learning portal prior to the flipped classroom activity, only fifty five percent among them reported that they had spent significant time in going through i-lectures and pre-reading materials. Eighty eight percent of the students agreed that physical arrangements were conducive for flipped classroom activity. All the students agreed that the instructor was actively engaging them in the learning process. Eighty two percent of students agreed that the method improved their self-efficacy to address the topics. All the students perceived that the flipped classroom activity was able to increase better understanding of the learning outcomes and recommended that more such sessions should be conducted for delivering the selected Medicine module.

A statistically significant difference of responses was observed for the following items: (a) classroom arrangements (positioning of the chairs for group activity, audio-visual facilities etc.) were conducive for the flipped classroom activity, (b) flipped classroom session inspired me to pursue further learning for the module and (c) instructor was able to provide clarification on difficult concepts during the flipped classroom activity. The respondents who either remained neutral or disagreed to any of these three above items were most likely to provide an overall negative feedback on the flipped classroom activity.

A statistically significant difference of responses was observed for the following items: (a) pre-reading materials and i-lectures were relevant for the flipped classroom activity, (b) activities during flipped classroom session increased my understanding of the key concepts, (c) more lectures should be conducted in the flipped classroom mode and (d) instructor was able to expand on i-lectures and pre-reading materials during the flipped classroom activity. The respondents who either agreed or strongly agreed to any of these four above items were most likely to provide an overall positive feedback on the flipped classroom activity.

4. Discussion

In this study, a large number of undergraduate medical students have lacked knowledge of systems of measures, had trouble performing basic numerical tasks and were unable to calculate mathematically the drug mass in solution precisely. The mean score decline in the pre-test across the three semesters indicate that our medical students were not informally picking up the requisite knowledge and skills during their MBBS studies.

Flipped classes enable instructors to engage the participants and facilitate them in critical thinking (Tucker, 2012) resulting in better understanding of the subject by promoting active learning (Mazur, 1991). In this study, the flipped classroom instructional model for Systems of Measure & Dosage Calculation Module replaced instructor-dominated lectures with highly interactive student-instructor activities. The scheduled lecture time was used primarily for assessing student knowledge and fostering active learning through activities in the form of an interactive Quiz session (Hake, 1998; Knight & Wood, 2005). Prerecorded i-lectures and pre-reading materials were viewed
independently by students prior to the flipped classroom activity. The primary purpose of this was to create an interest in active learning and transmission of information. The participants were repeatedly exposed to the content of the selected topics and subjected to a series of assessments that included a Quiz (pre-test) during the flipped classroom activity, a formative assessment and reinforcement followed by a final End of Semester Examination. These activities were expected to invoke active learning among the participants, resulting in better performance and culminating in higher achievements (Hake, 1998; Knight & Wood, 2005).

A study conducted by Pierce & Fox (2012) on Vodcasts and Active-Learning Exercises in a “Flipped Classroom” Model of a Renal Pharmacotherapy Module reported that the student performance on final examination questions relating to the renal module significantly improved from 2011 to 2012. The improvement in student performance was believed to be due to repeated exposure to the concepts through pre-test followed by process-oriented guided inquiry learning (POGIL) activity, and post-test (Pierce & Fox, 2012).

Studies by Gardner (2006), Litzenger et al. (2011) and Olds & Johri (2011) also reported that the students expressed a consistently high preference for the flipped classroom instructional model relative to the traditional instructor-led lecture model. They recognized the convenience and pedagogical benefits of the flipped classroom instructional model. They demonstrated the efficacy of active learning using the flipped classroom model to improve student outcomes. It was observed that the flipped classroom supported the fact that the quality (not necessarily the quantity) of student-teacher interaction was a compelling force in improving student performance (Gardner, 2006; Litzenger et al, 2011; Olds & Johri, 2011).

In our study, a combination of Systems of Measure & Dosage Calculation-Flipped Classroom Session (SMDC-FCS) and Poll Everywhere was successful in engaging attention, facilitating participation and learning among three cohorts of undergraduate medicine students for delivering the Systems of Measure & Dosage Calculation Block in a university setting. It provided opportunities for the participants to get engaged in active learning and apply their knowledge in problem solving scenarios during the formative assessment. It was also effective in preparing the students for the final End of Semester Examination.

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