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RESEARCH ARTICLE

Comparison of teaching methods: Formative assessment in traditional didactic lectures and learning monitoring system-based lectures

Nakagawa Naoto
School of Pharmaceutical Science, Ohu University, Koriyama, Fukushima, Japan

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Correspondence
Naoto Nakagawa
School of Pharmaceutical Science
Ohu University
Koriyama
Fukushima
Japan
n-nakagawa@pha.ohu-u.ac.jp

Abstract

Background: Studies comparing formative assessment in traditional lecture settings and those incorporating Information and Communication Technology (ICT) tools are available, although direct head-to-head comparisons are less common. **Objective**: This study evaluated the effectiveness of formative assessment (FA) incorporating a learning monitoring system (LMS) as ICT in teaching methods, specifically in flipped classrooms, flipped classrooms and spaced learning, and traditional formative assessment (FA/TDL) to improve student learning outcomes. **Methods:** Pharmacy students in a drug-information course were divided into three groups: traditional formative assessment (FA/TDL; 68 students), flipped classroom (FA/FC/LMS; 74 students), and flipped classroom with spaced learning (FA/(FC+SL)/LMS; 74 students). The primary outcome measured was the mean difference in external mock test scores adjusted by grade-point averages (GPAs). Secondary outcomes identified factors influencing these score differences. **Results:** The results demonstrated that the learning method significantly impacted learning outcomes, with LMS improving learning outcomes compared to FA/TDL. Factors affecting test scores included sex, GPA, and the teaching methods used in the FA/FC/LMS and FA/(FC+SL)/LMS groups. **Conclusion:** This study suggests that implementing LMS in higher education can enhance student performance and support successful graduation.

Introduction

Didactic lectures have traditionally been used in classes across academic fields because they are easy to conduct and allow lecturers to provide substantial information on a particular topic to many students simultaneously (Miller *et al.*, 2013). However, some researchers have suggested that one-way communication between lecturers and students, which restricts interaction, sharing, and student engagement, is a key disadvantage of didactic lectures (Young *et al.*, 2009). Additionally, students' engagement with lecture content gradually declines after ten to twenty minutes (Wilson & Korn, 2007). Although proficiency-based education has been shown to improve learning outcomes through peer effects (Duflo *et al.*, 2011). However, some drawbacks are associated with implementing this approach. Therefore, it is necessary to identify effective teaching methods to improve learning outcomes in didactic lectures.

Active learning is a learner-centred method involving active participation through reading, writing, or in-class discussion (Torralba & Doo, 2020). The advantages of active learning for students include acquiring pre-existing knowledge beforehand and enabling them to ask meaningful questions from faculty members during class. The faculty members, in turn, can go beyond lecturing, as they are provided with the opportunity to expand their teaching skills and receive immediate feedback during their engagement with students to assess the effectiveness of their teaching techniques. Some examples of active learning include pauses for reflection or "*muddiest*" points (Merritt *et al.*, 2018), harvesting (Merritt *et al.*, 2018), hands-on technology (Medina, 2017), and problem-based learning or case studies (Medina, 2017). Active learning has been comprehensively researched globally (Grzych & Schraen-Maschke, 2019; Hussain & Wilby, 2019; Sivarajah *et al.*, 2019).

A flipped classroom (FC) is an active learning method widely used in higher education. In a pharmacology course, audience response systems and FC + audience response systems were more effective teaching methods than traditional face-to-face lectures (Nakagawa & Yamashita, 2022). Furthermore, the effectiveness of FC increases when a higher proportion of students watch the recommended pre-lecture videos in advance. However, despite FC having a greater effect on short-term memory retention, it has no major impact on long-term memory retention (Nakagawa, 2021). Nonetheless, practical implementation of FC may be valuable since the students' perception of FC was better than that of traditional methods (Kugler *et al.*, 2019). Thus, the use of learning monitoring system (LMS) systems needs to be examined to further improve the learning outcomes of pharmacy students in an FC setting of didactic lectures.

Previous studies have produced controversial results regarding using information and communication technology (ICT) in education. For instance, prior research on fourth-grade students found no significant difference in outcomes between application-based and teacher-directed instruction (Bryant *et al.*, 2015). Similarly, a meta-analysis of K-12 classrooms concluded that educational technology applications positively affect mathematics achievement, although this impact was negligible (Cheung & Slavin, 2023). In higher education, online, hybrid education in computer science was more effective than face-to-face instruction, though the difference did not exceed 10% of the point maximum (Charytanowicz, 2023). Additionally, a virtual learning environment outperformed traditional lectures in an occupational safety engineering course in higher education (Koskela *et al.*, 2005). Despite these findings, ICT remains a valuable tool, and its effectiveness warrants further validation.

Research suggests that spaced learning (SL) is one of the most effective teaching methods (Terenyi *et al.*, 2019; Boettcher *et al.*, 2021; Kornmeier *et al.*, 2022). It involves spacing out quizzes to increase long-term memory retention of course material (Noor *et al.*, 2021). There are two types of SL: "*absolute spacing*" and "*relative spacing"*. The term "*absolute spacing*" refers to the total amount of time across all study intervals in which an item is studied multiple times. For example, consider a scenario where a word is studied four times with two-minute intervals between each session. In this case, the absolute spacing for the word is six minutes (two minutes multiplied by three times equals six minutes), as there are three intervals of two minutes each.

The term "*relative spacing*" refers to how each learning opportunity is distributed. Relative spacing has been categorised as "*expanding spacing*", "*equal spacing*", and "*contracting spacing"*. In psychology and linguistics, "*expanding spacing*" is the most effective (Nakata, 2018). However, it reportedly increases short-term but not long-term memory retention (Kanayama & Kasahara, 2016). Moreover, the effects of "*expanding spacing*" have not always been consistent (Nakata, 2015), suggesting that further research is required.

Formative assessment (FA) improves students' understanding (Prashanti & Ramnarayan, 2019; Say *et al.*, 2022). FA is the process of appraising, judging, or evaluating students' work or performance and using it to shape and improve students' competence; it is an assessment of learning (Prashanti & Ramnarayan, 2019). This study examined the effect of FA across different teaching methods. In traditional didactic lectures, FA is defined as assessing students' understanding of topics using multiple-choice questions provided on paper at the end of each lecture. Following the assessment, corrected answer sheets are distributed to students by the lecturer. FA has been widely applied in both traditional didactic lectures and ICT-based teaching. Comparative learning outcomes between FA in didactic lectures and FA in ICT-based teaching methods are of academic interest due to the lack of prior direct comparison.

This study aimed to evaluate the effectiveness of FA in traditional didactic lectures compared to its implementation in flipped classrooms (FC) with spaced learning (SL) using a learning monitoring system (LMS) as ICT to improve student learning outcomes. Outcome measures included the differences in external mock test scores on a knowledge-based drug information section. This study used pharmacy students enrolled in a drug information course as an example, but the findings may apply to any academic field.

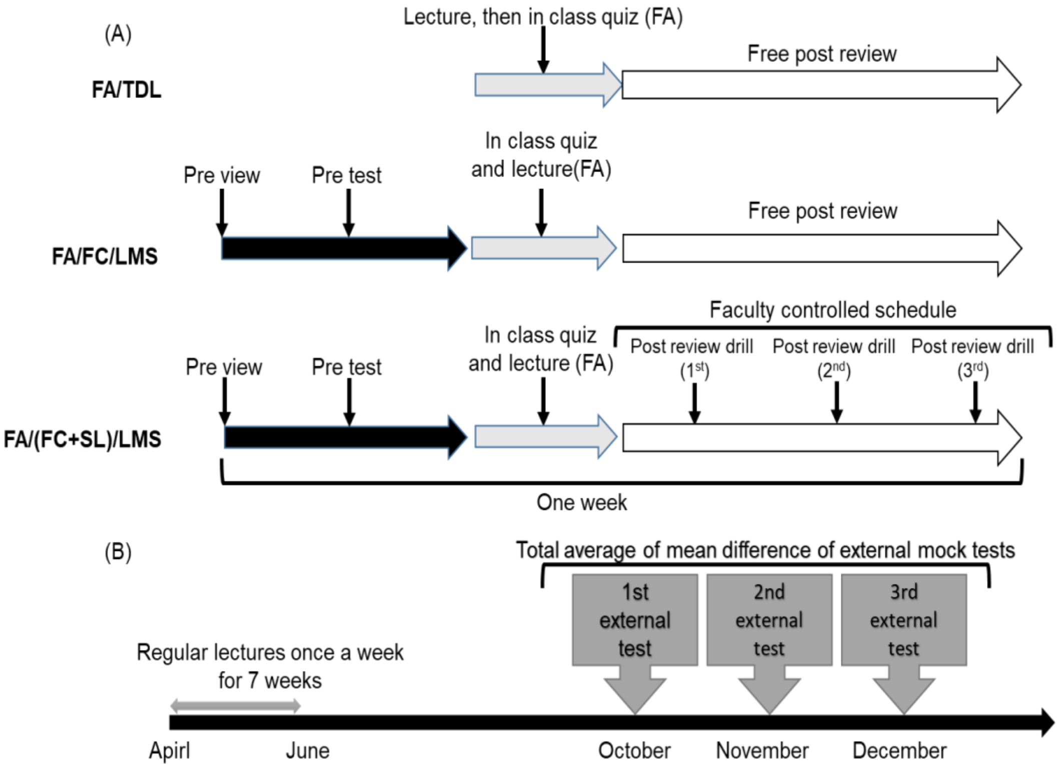
Methods

Design

The drug information course, comprising seven knowledge-based topics, was presented to fourth-year (P4) students during a six-year pharmacy programme in

Japan; lectures were given on Wednesdays throughout the first quarter.

The study design is illustrated in Figure 1(A). The targeted population comprised P4 pharmacy students enrolled at a Japanese university in 2018, 2020, and 2022. The three interventions were conducted across different academic years, introducing the potential for "*natural expected variation*" bias in the evaluation (Boevé *et al.*, 2019). To mitigate this bias, we applied the mean difference in external mock test scores (adjusted by grade-point averages (GPAs)) for the drug information section within each intervention. These scores were normalised by subtracting the average national score. The design was deemed appropriate as the study focused on the effectiveness of different FA teaching methods. Figure 1(B) outlines the evaluation scheme in the study. However, since the design assumed classroom environments equipped with LMS, classrooms lacking LMS were regrettably excluded from the study.



FA = Formative Assessment; FC = Flipped Classroom; SL = Spaced Learning; TDL = Traditional didactic lectures, LMS = Learning monitoring system.

Figure 1: (A) Study scheme per week in the drug-information course (B) Evaluation scheme.

A learning monitoring system (C-learning NETMAN, Shizuoka, Japan; https://www.netman.co.jp/) was installed as the ICT system, which could be accessed and used from laptops or mobile phones. When necessary, faculty members could control video files, pre-tests, and drill functions from their mobile phones, while students could view videos, answer pre-test questions, and complete drills. The FC + audience response systems have been discussed previously (Nakagawa, 2021).

Materials

The following factors were selected for analysis: sex (female or male), GPA, correct percentage of pre-test answers, correct percentage of in-class quiz answers, number of drills, and incentives. The primary outcome was the mean difference in external mock test scores (adjusted by GPAs) for the drug information section within each intervention, expressed as individual scores subsidised by the average national score. The external mock tests were knowledge-based. The reason for the GPA-based adjustment is that GPA is significantly associated with learning outcomes, such as pharmacist licensing examination scores (Chisholm-Burns *et al.*, 2017; Alhifany *et al.*, 2020; Daugherty & Malcom 2020).

As the present study results might be confounded by GPA, an analysis of covariate (ANCOVA) with GPA as a covariate was performed. The secondary outcomes were the factors that positively or negatively influenced the differences in external mock test scores. Multiple regression analyses were performed to identify the factors significantly affecting the primary outcome, including sex, in-class quiz scores, teaching method, and GPA. A variance inflation factor of >5 generally indicates multicollinearity (Varady *et al.*, 2023).

Procedures

First, FA in the traditional didactic lectures (FA/TDL) was used in 2018. An in-class quiz for each topic was delivered at the end of the class; it had multiple-choice question handouts for FA and scantrons. After submitting the scantrons to the lecturer, correct answer sheets were provided to the students.

FA in the FC with LMS (FA/FC/LMS) was the mode of delivery in 2020. Incentives were offered to students based on improvements in learning outcomes (Nakagawa, 2021). Incentives for studying can effectively encourage engagement in study subjects and improve learning outcomes (Fryer, 2011). Students received one point each for watching a recorded lecture video in the LMS, finishing a pre-test in the LMS, attending a lecture, and responding to an in-class quiz in the LMS.

Lastly, FA in the FC+SL with LMS (FA/(FC+SL)/LMS) was presented using the same systems in 2022, with intermittent weekly three-day drills. As incentives, students received one point each for watching a recorded lecture video in the LMS, finishing a pre-test in the LMS, attending a lecture, responding to an in-class quiz in the LMS, and participating in drill practices three times a week. The reason for setting the weekly three-day drills was as follows: The well-known Ebbinghaus' classic forgetting curve, published in the 1880s, has been widely referred to in research on learning (Wixted & Carpenter, 2007; Murre & Dros, 2015). Some researchers who tried to replicate this phenomenon have concluded that it is not completely smooth and most likely includes an increase starting at the 24-hour data point (Murre & Dros, 2015). They also pointed out that the first night of sleep after learning has a particularly important effect on memory that may continue to evolve for several days thereafter.

Additionally, the one-day saving score was higher than the eight-hour score, and the two-day saving score was higher than the expected score (Murre & Dros, 2015). Considering these findings, regular, intermittent three-day weekly drills were speculated to be more effective for retaining knowledge.

Review drills were prepared by increasing the number of questions per topic (Table I). The pooled questions were drawn from a computer-based exam database (Sundai Advanced Teaching Technology, Tokyo, Japan, Pharmacy Education Support System; https://satt.jp/product/ess/index.html).

Table I: Drill contents

Review drill	Number of applied questions	Number of pooled questions	Assigned topic
First	10	10	1
Second	15	31	1 and 2
Third	20	53	1, 2 and 3
Fourth	25	67	1, 2, 3 and 4
Fifth	30	82	1, 2, 3, 4 and 5
Sixth	35	93	1, 2, 3, 4, 5 and 6
Seventh	50	116	1, 2, 3, 4, 5, 6 and 7

Analytical strategy

Student's t-test and analyses of variance (ANOVA) were conducted for parametric distributions. The Mann-Whitney U-test and the Kruskal-Wallis test were conducted for non-parametric distribution data. Fisher's exact and chi-square tests were used to analyse categorical data. An ANCOVA was performed when there was a significant difference in background information among the three cohorts. A p-value < 0.05 was considered statistically significant.

The sample size was calculated using G*Power (Heinrich-Heine-Universität Düsseldorf; https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower.html).

F-tests were used, and statistical analyses were performed using the ANOVA fixed effect, omnibus, one-way, and a priori power analyses. The required sample size was calculated using the following input parameters: effect size, 0.25; alpha error probability, 0.05; power, 0.8; number of groups, three. A total of 159 students were required to detect a difference among the three interventions. Statistical methods were appropriately applied depending on data distribution using EZR (‘*Easy R’*) for R (Kanda, 2013). Statistical significance was set at $p < 0.05$.

Ethical consideration

This study was approved by the ethics committee of the university (approval number 323) that hosted the study. The goal of the study was described to P4 students each year using a letter at the course’s final lecture, after which they handed in their written informed consent to participate in the study.

Results

Participant characteristics

A total of 68, 74, and 74 P4 students participated in the FA/TDL, FA/FC/LMS, and FA/(FC+SL)/LMS interventions, respectively (Table II). These participants satisfied the precalculated sample size of 159. The sex distribution in the FA/TDL, FA/FC/LMS, and FA/(FC+SL)/LMS groups was 41:27, 46:28, and 41:33, respectively, and did not differ among the three teaching methods (p = 0.697). The median GPA values in the FA/TDL, FA/FC/LMS, and FA/(FC+SL)/LMS groups were not significantly different (p = 0.114), at 2.80, 2.55, and 2.80, respectively. The pre-test scores in the FA/FC/LMS and FA/(FC+SL)/LMS groups were not significantly different (p = 0.490), at 72.9% and 65.7%, respectively. Those in-class quizzes were significantly different ($p < 0.001$), at 90.0%, 55.0%, and 44.6%, respectively. The number of drills in the FA/FC/LMS and FA/(FC+SL)/LMS groups was 7.5 and 17.0, respectively; the values were not significantly different (p = 0.170). The incentive scores between the FA/FC/LMS and FA/(FC+SL)/LMS groups were significantly different ($p < 0.001$) at seven (interquartile; IQR 5–7) and three (IQR 0–5), respectively.

Table II: Demographic backgrounds

Parameters	Traditional didactic	Learning monitoring system		*p*	Statistical test
Teaching method	**FA/TDL (A)**	**FA/FC/LMS (B)**	**FA/(FC+SL)/LMS (C)**	-	-
Sex (female: male)	**41:27**	**46:28**	**41:33**	**0.697**	**Fisher’s exact**
GPA, median (IQR)	**2.80 (2.58-3.23)**	**2.55 (2.30-3.08)**	**2.80 (2.20-3.30)**	**0.114**	**Kruskal-Wallis**
Pre-test (%), median (IQR)	**NA**	72.9 **(57.5–81.4)**	65.7 **(54.2–81.4)**	**0.470**	**Mann–Whitney *U***
In-class quiz, median (IQR)	90.0 **(86.0–93.3)**	55.0 **(44.6–62.5)**	44.6 **(37.9–54.3)**	< 0.001* A:B < 0.001* A:C < 0.001* **B:C < 0.003***	Kruskal–Wallis **Post-hoc: Bonferroni**
Drill (total times), median (IQR)	NA	7.5 (0–23)	17.0 (12–20)	0.170	Mann–Whitney *U*
Incentives (max 7), median (IQR)	NA	7 (5–7)	3 (0–5)	< 0.001*	Mann–Whitney *U*

FA, Formative assessment; FC=Flipped classroom; SL= Spaced learning, GPA=Grade-point average; IQR, interquartile range.

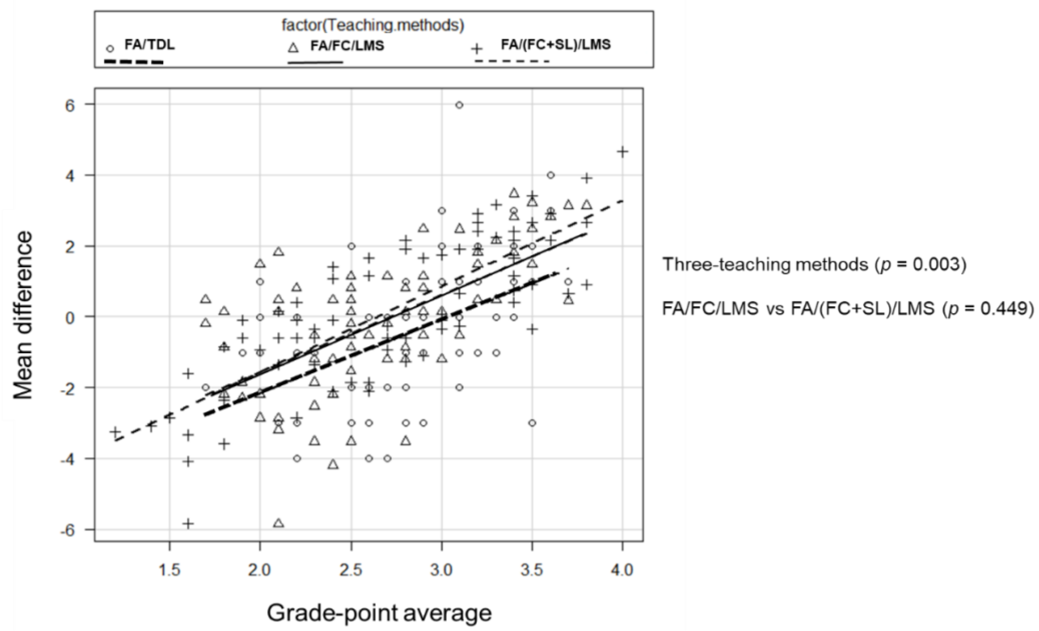
Primary outcomes

The data followed a parametric distribution (Shapiro-Wilk normality test: p-value = 0.301). Accordingly, the mean differences and standard deviations (SD) of external mock test scores were calculated and are shown in Table III. The values for the FA/TDL, FA /FC/LMS, and FA/(FC+SL)/LMS groups were −0.396 (SD 2.14), −0.138 (SD 1.93), and 0.169 (SD 2.09), respectively. These results suggested a trend of improvement across the teaching methods. However, the differences among the three groups were not statistically significant (p = 0.262). Figure 2 shows the ANCOVA results. Significant differences were observed among the three teaching methods (p = 0.003); however, significant differences were not observed between the FA/FC/LMS and FA/(FC+SL)/LMS (p = 0.449) groups. ANCOVA could not be performed owing to significant interactions among the group variables and covariates of the in-class quiz (p = 0.007).

Table III: Primary outcomes

Parameters	Traditional didactic	Learning monitoring system		*p*-value
Teaching method	FA/TDL	FA/FC/LMS	FA/(FC+SL)/LMS	
Average difference in the external mock test scores (Standard deviation)	- 0.396 (2.14)	- 0.138 (1.93)	0.169 (2.09)	0.262

FA=Formative assessment; FC, Flipped classroom; SL=Spaced learning.



FA = Formative assessment; FC = Flipped classroom; GPA = Grade-point average; SL= Spaced learning, TDL =Traditional didactic lectures, and LMS = Learning monitoring system.

Figure 2: The three teaching methods (*p* = 0.003), FA/FC/LMS vs FA/(FC+SL)/LMS (*p* = 0.449).

Secondary outcomes

Table IV summarises the results of the multiple regression analysis. The variance inflation factor of the four variables ranged from 1.12 to 4.47, indicating that the analysis had a low chance of multicollinearity and was reliable. Variables significantly associated with the mean difference in the external mock test scores included sex (p = 0.045), GPA (p < 0.001), teaching method for FA/FC/LMS (p = 0.003), and teaching method for FA/(FC+SL)/LMS (p = 0.003) (estimated regression coefficients: 0.46, 2.17, 1.24, and 1.51, respectively). GPA had the strongest association, followed by the FA/(FC+SL)/LMS and FA/FC/LMS teaching methods.

Table IV: Multiple regression analysis

Parameters	VIF	Regression coefficient estimate	95% Confidence interval	Standard error	*t*-statistics	*p*
Sex (Male)	1.12	0.46	0.01-0.91	0.23	2.01	0.045*
GPA	1.56	2.17	1.72-2.61	0.23	9.59	< 0.001*
In-class quiz	4.47	0.02	-0.004-0.037	0.01	1.61	0.110
Teaching methods (FA/FC/LMS)	3.69	1.24	0.42-2.07	0.42	2.96	0.003*
Teaching methods (FA/(FC+SL)/LMS)	3.69	1.51	0.55-2.47	0.49	3.11	0.003*

GPA, grade-point average; FA, formative assessment, FC, flipped classroom; SL, spaced learning; LMS, learning monitoring system; VIF, variance inflation factor., *: Statistically significant

Discussion

This study evaluated the effectiveness of FA in traditional didactic lectures, FC with LMS, and FC + SL using LMS to improve student learning outcomes. The outcomes were measured by differences in external mock test scores on the drug information section, which focused on knowledge-based content. As a result, teaching methods that utilised LMS significantly improved student learning outcomes compared to didactic methods. This finding suggests that LMS plays a critical role in enhancing student understanding in knowledge-based classes. Teaching methods using LMS have some advantages. First, LMS is useful for summarising student understanding by gathering their responses to multiple-choice questions (Tuma, 2021). For example, in this study, an in-class quiz on a particular topic in the FA/FC/LMS was available to students immediately after the lecture, thus enabling the lecturer to determine how much the students understood the topic. This led the lecturer to incorporate the students' understanding and further deepen their knowledge in future sessions. In contrast, in the FA/TDL, multiple-choice questions are administered through paper-based tests at the end of the class; therefore, timely responses from students based on their understanding are impossible. This is because FA's learning outcomes differ between traditional didactic lectures and teaching methods implementing LMS.

Despite the above advantages, learning outcomes using ICT are controversial. A previous study demonstrated that a teaching method using FC with ICT resulted in positive learning outcomes (Kim *et al.*, 2017; Wu *et al.*, 2022). However, a study using virtual reality technology reported that this teaching method may not always be more effective than didactic learning regarding increasing comprehension (Kaphingst *et al.*, 2009). Another study using e-learning, which has the benefits of flexibility and freedom in planning learning schedules, also reported no positive outcomes (Kelly *et al.*, 2009). Additionally, a meta-analysis revealed that e-learning did not significantly improve the knowledge, skills, and clinical behaviour of health professionals and students in higher education (Fontaine *et al.*, 2019).

In contrast, blended learning, which combines face-to-face learning with e-learning, has demonstrated better outcomes than traditional learning in healthcare education (Vallée *et al.*, 2020; Liu *et al.*, 2024). Based on these findings, while e-learning alone may have a limited impact on learning outcomes, combining face-to-face lectures with ICT-based learning methods such as FC can effectively enhance student understanding. As the present study used FC with ICT, teaching methods with ICT may be more innovative than traditional didactic methods.

The effects of SL in combination with ICT have been previously described, although the results were not significant (Choe *et al.*, 2022). The previous study utilised spaced learning at a frequency of two times every two weeks. The present study set spaced intervals to three days per week. However, significant differences between the FA/FC/LMS and FA/(FC+SL)/LMS groups were not observed, implying that SL does not improve student learning outcomes. The spaced interval for FA/(FC+SL)/LMS was set based on Ebbinghaus' classic forgetting curve. Although this method has a theoretical basis, satisfying the incentive requirements might be demanding for students in FA/(FC+SL)/LMS. The results of the incentive scores demonstrated that the scores for FA/(FC+SL)/LMS were significantly lower than those for FA/FC/LMS. Therefore, the true effectiveness of SL was not demonstrated. It is possible that the faculty-controlled schedule did not function effectively.

The present study also verified that male students exhibited significantly negative learning outcomes using LMS. A previous study has reported that boys typically have higher confidence in their ICT skills than girls, while girls may perform better in certain ICT-related tasks; nevertheless, girls tend to have better self-regulation and use learning tools more frequently than boys, which might contribute to their improved performance in some ICT-based learning environments (Campos & Scherer, 2024). Therefore, the results of the present study could be similar.

This study had some limitations. First, interventions across years, which may have contributed to 'natural expected variation' bias, were compared (Boevé *et al.*, 2019). However, the differences in external mock test scores that expressed individual scores subsidised by the average national score were evaluated, and ANCOVA was performed among the teaching methods. Therefore, the expected natural variation could be reduced. To obtain more robust evidence, a cross-sectional or randomised investigation is required. Second, a long-term effect comparison among the three teaching methods was not made in this study. The study focused on the learning outcomes of different teaching methods within the same year, evaluating only the short-term effects. Therefore, future studies should compare the long-term learning outcomes of external mock tests among the three teaching methods.

The results of this study revealed that FA by teaching methods using LMS improved student learning outcomes compared to traditional didactic lectures, suggesting that active learning with LMS may enhance student learning outcomes. As LMS can be remote-controlled by faculty members using their smartphones, the system can be installed on all learning equipment at any education level. Cross-sectional or randomised controlled design studies are required to confirm the present study findings and verify that LMS improves learning outcomes across academic fields. Implementing this learning method would ensure that students who study their specialities using LMS at higher levels of education can successfully graduate from their schools, colleges, or universities, thus laying the foundation for an educationally advanced society in the future.

Conclusion

This study assessed the effectiveness of FA teaching methods that integrate LMS with traditional didactic lectures. Specifically, it focused on flipped classroom models utilising audience response systems as part of the FA/FC/LMS approach. This innovative teaching strategy was compared to the more conventional method of traditional didactic lectures (FA/TDL) to evaluate its impact on improving student learning outcomes. By leveraging ICT tools, the FA/FC/LMS approach aimed to foster an interactive and engaging learning environment, encouraging active student participation and enhancing knowledge retention.

These findings suggest that incorporating LMS into higher education curricula, particularly in professional programs such as pharmacy, substantially supports student learning and academic success. Additionally, this approach can be adapted and applied across various disciplines in higher education, helping students to achieve their educational goals and successfully graduate from their programs.

Data availability statement

Dryad, Dataset,
https://doi.org/10.5061/dryad.gxd2547vk

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Conflict of interest

The authors declare no conflict of interest.

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