



Effectiveness of a Web-based Flipped Classroom in Pharmacology and Doping Learning

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Abstract

Study Purpose: This study examines the effectiveness of a web-based flipped learning model to improve the learning achievement of sports science students in pharmacology and doping courses after controlling for students' initial abilities.

Materials and methods: A quasi-experimental pretest-posttest control group design was implemented in the Sport Science Study Program, Universitas Negeri Padang. Thirty students participated, comprising 15 students in a conventional classroom group and 15 students in a Moodle-supported web-based flipped classroom group. Learning devices and instruments were evaluated by three experts. Achievement was measured with a 50-item test with acceptable reliability (Cronbach's alpha = .788). Posttest scores were analyzed through analysis of covariance using pretest score as the covariate.

Results: The learning model significantly affected adjusted posttest scores, $F(1, 27) = 21.344$, $p < .001$, partial eta squared = .442. The adjusted posttest mean was 36.64 for the flipped classroom group and 28.70 for the conventional classroom group.

Conclusion: Structured LMS-based preparation combined with classroom case discussion improved cognitive achievement in Pharmacology and Doping learning. These findings support active web-based learning in sport science and indicate the need for broader studies examining engagement and clean-sport literacy.

Keywords: ANCOVA, Flipped Classroom, Learning Achievement, Pharmacology and Doping, Web-Based Learning

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Introduction

The rapid expansion of digital learning in higher education has changed the way lecturers organize instruction, communicate with students, and assess learning progress. Learning management systems, instructional videos, online quizzes, digital modules, web-based discussion forums, and learning analytics are now widely used in university courses. However, technology alone does not guarantee meaningful learning. Digital resources become educationally valuable only when they are placed within a coherent pedagogical design that guides students to prepare before class, participate actively during class, and consolidate learning after class.

The flipped classroom provides one instructional response to this challenge. Rather than using classroom meetings mainly for one-way content delivery, the flipped model moves initial exposure to learning materials into the pre-class phase and reserves synchronous meetings for clarification, application, discussion, and problem solving. In this arrangement, students are expected to engage with basic concepts through videos, readings, quizzes, or online modules before meeting the lecturer. Classroom time can then be used to address misconceptions, analyze cases, and apply concepts to authentic problems. Recent umbrella and bibliometric reviews have consolidated the logic of this arrangement ([ElGamal & Zawacki-Richter, 2025](#); [Oknaryana et al., 2025](#)), while [Baig and Yadegaridehkordi \(2023\)](#) showed that current higher education implementations commonly rely on learning management systems, videos, collaborative tools, content repositories, and online assessment resources. Their review also indicates that successful implementation requires alignment among learning objectives, pre-class preparation, in-class engagement, and assessment tasks.

Evidence from health-related education further supports the relevance of flipped learning. [Naing et al. \(2023\)](#) found that flipped classrooms may improve academic performance and support students' satisfaction in undergraduate health professional programs. [Oudbier et al. \(2022\)](#) emphasized that effectiveness in health sciences is associated with deliberately connected pre-class, in-class, and post-class activities, while [Park et al. \(2021\)](#) identified benefits for self-directed learning, self-efficacy, and problem-solving when learning designs are tailored to course characteristics. [Spaic et al. \(2025\)](#) further concluded, through a systematic review and meta-analysis, that flipped classroom strategies in medical education can enhance learning outcomes when they are implemented as structured active learning rather than as a mere replacement of lectures with videos. These findings are important because health and sport science courses require students not only to remember concepts but also to interpret evidence, solve problems, and make decisions in practical contexts.

The Pharmacology and Doping course in a sport science curriculum has a distinctive learning profile. Students must understand basic pharmacological concepts such as pharmacokinetics, pharmacodynamics, adverse effects, drug interactions, supplement use, and medication safety. At the same time, they need to connect those concepts to sport-specific issues, including prohibited substances and methods, health risks for athletes, ethical responsibilities, and anti-doping regulations. Despite the growing body of research on flipped classrooms in general higher education, medical education, and pharmacy education, empirical evidence on web-based flipped learning specifically designed for a course that integrates pharmacological knowledge with sport-specific anti-doping literacy and ethical reasoning remains scarce. This gap is notable because Pharmacology and Doping requires more than factual recall: students must apply pharmacological principles to athlete-specific decisions, a combination of cognitive and applied-ethical demands that is rarely addressed together in the flipped-classroom literature reviewed above. Recent evidence in pharmacology and pharmacy education indicates that flipped learning can support achievement and application-oriented learning when online preparation is paired with interactive classroom activity ([Cui et al., 2023](#); [Wu et al., 2022](#)). A lecture-dominated approach may deliver information efficiently, but it can

leave insufficient time for regulatory interpretation, case analysis, and guided reasoning. For this reason, Pharmacology and Doping requires a learning model that supports prior preparation and turns classroom time into an opportunity for higher-order learning.

Universitas Negeri Padang uses the Moodle-based learning management system as a platform for both online and blended learning. However, the fact that materials are simply uploaded to an LMS does not mean that web-based learning itself is well-designed. A class may be rich in digital resources yet still be highly teacher-centered if students just download the files and come to lectures instead of being engaged in other ways. For this reason, the web-based flipped classroom was the learning method selected for this study. This strategy entails very well-planned modules, videos, quizzes, forums, assignments, and feedback in a well-organized progression of learning activities. It also gives instructors the time and environment in face-to-face meetings to explore such things as case studies, concepts, and practical applications in sports.

Premise of this approach became stronger post-COVID-19 pandemic. During those days, the bulk of student learning at Universitas Negeri Padang was online with teachers depending heavily on students doing things on their own at different rates as online materials would be asynchronous. After the pandemic, the university implemented the policy that allows blending of online and offline teaching in a ratio of 50:50; which implies that a significant percentage of teaching time must be through online means.

Still, practical observations showed that though many lecturers have been using Internet-based tools to deliver instructional materials, those materials are not generally in a form that really lends itself to self-regulated learning and they often get uploaded without providing a larger picture as an anchor for students' progress in learning through online media independently and in a productive way. This disconnect between the university's vision of heavy reliance on online learning and the current level of that learning quality highlights the vital need for a design that can be both a new idea and yet also a good example of how such learning can be organized in its online phase and be truly independent.

This study offers three contributions. First, it applies the web-based flipped classroom to Pharmacology and Doping, a course that combines pharmacology, athlete health, sport ethics, and anti-doping literacy. This context remains less frequently examined than general higher education, medical education, language learning, or broad health professional education. Second, the study evaluates the effect of the learning model using ANCOVA, so the comparison of posttest achievement takes students' initial ability into account. Third, the study validates learning devices and instruments before the intervention, thereby strengthening the methodological basis for interpreting the experimental results.

This gap raises the central problem addressed by the present study: whether a web-based flipped classroom model can produce a significantly greater improvement in students' learning achievement in the Pharmacology and Doping course than conventional classroom instruction, after students' initial ability is statistically controlled.

Based on this background, the study aimed to determine the effectiveness of a web-based flipped classroom model in improving students' learning achievement in a Pharmacology and Doping course after controlling for pretest scores. The practical objective was to provide evidence for the design of LMS-supported learning in sport science courses that require conceptual mastery, case-based discussion, and ethically informed decision making.

Materials and methods

Study participants

The study was conducted after obtaining permission from the study program. Students were informed about the learning activities, research purpose, use of data, and confidentiality of identity. Participation did not reduce students' academic rights because the intervention was

integrated into planned learning activities. Student identities were anonymized, and the data were used only for academic analysis.

The participants were 30 students enrolled in the Sport Science Study Program, Faculty of Sport Science, Universitas Negeri Padang, during the January-June semester of the 2025 academic year. The sampling technique was total sampling of the accessible population in the two intact classes: all students who were enrolled in the relevant course and available for the complete intervention were included, while students who did not meet these criteria — for example, those who did not complete the full intervention or did not complete both the pretest and posttest — were excluded from the analysis. Fifteen students were assigned to the conventional classroom group, and 15 students were assigned to the web-based flipped classroom group. Because the study used existing classes, individual random sampling and individual random assignment were not performed; the classes served as the comparison units. The sample size followed the number of students available in the existing classes. Although the number of participants was limited, such a condition is common in class-based quasi-experimental research. Therefore, the findings should be interpreted primarily as evidence of internal effectiveness in the observed course context rather than as a basis for broad population generalization.

The participants consisted of 19 male students and 11 female students. The conventional classroom group included nine male and six female students, whereas the web-based flipped classroom group included ten male and five female students. A pretest equivalence test was conducted to examine whether the two groups had comparable initial ability before the intervention.

Study organization

A quasi-experimental method with a pretest-posttest control group design was used. This design was appropriate because the study was conducted in existing classes in an authentic instructional setting, where full individual randomization was not feasible (Creswell & Creswell, 2023). The control class received conventional classroom instruction, while the experimental class received web-based flipped classroom learning. Pretest scores were used as a covariate because students' initial ability can influence posttest achievement and may confound a direct comparison of final scores.

ANCOVA was selected because it enables the researcher to compare posttest outcomes after statistically adjusting for variation in pretest scores. In classroom-based studies, students often enter the intervention with different levels of prior knowledge. If these differences are ignored, the estimated effect of the instructional model may be biased. By including the pretest score as a covariate, ANCOVA provides a more controlled estimate of the treatment effect than a simple comparison of posttest means, provided that assumptions such as homogeneity of regression slopes are satisfied (Jung et al., 2025; Köhler et al., 2020; Lüdtke & Robitzsch, 2025).

The intervention was carried out over a period of eight weeks. During week one the orientation took place, students were presented with a thorough introduction to LMS, the flipped classroom model had been explained, students had been provided with the pretest. The remaining two to seven weeks mainly included the learning activities with students being tested after eight weeks, the period reserved for the reflection, the review, and the posttest.

In the web-based flipped classroom group of classes, the students actively participated in Moodle-based LMS at Universitas Negeri Padang. Learning phases were divided into three very close parts through the learning process. The first pre-learning stage was designed for the students to be actively learning the materials through the textbooks, articles, lectures, and videos. The formative quizzes and their submission of questions or notes that will be very beneficial to their understanding were included in this phase. The second class phase involved

the lecturers presenting, the students doing their group reports, case discussions, and problem-solving activities being done in the form of a team. Students were engaged with the help of the lecturer and also doing practical work. The lecture-based phase was also used for explaining new concepts. The students also reflected on learning through this post-class phase and the assignments were of higher levels with regard to students being in a forum and the students themselves responding to the feedback provided. The entire learning system was a very carefully designed way of combining the self-study by the students, their involvement during the classroom time, and their ability to put all learning into the real-life activities.

The topics covered included drugs and supplements, pharmacokinetics, pharmacodynamics, adverse effects and drug interactions, pharmaceuticals and their use in sports settings, risks to health side effects of sports, doping prohibited substances doping methods action mechanisms, and health aspects of doping. Meanwhile, the teacher in the regular classroom gave a lecture or presentation, followed by students doing Q&A and homework after class time. The main differences between the two groups of students were the time spent in the structured pre-class preparation the amount of learning via LMS, and the time spent in face-to-face sessions for hands-on activities.

Statistical analysis

The data were analyzed using descriptive and inferential statistics. Descriptive statistics were used to summarize pretest and posttest scores by group. Inferential analysis was conducted using ANCOVA, with posttest score as the dependent variable, learning model as the independent variable, and pretest score as the covariate. Assumption testing and interpretation of effect size followed established applied statistical guidance (Field, 2024; Pallant, 2020; Tabachnick & Fidell, 2019).

Several assumptions were examined before interpreting the ANCOVA results. Residual normality was tested using the Shapiro-Wilk test. Homogeneity of variance was examined using Levene's test. The association between the covariate and the dependent variable was examined using Pearson correlation. Homogeneity of regression slopes was tested by examining the interaction between learning model and pretest score. The level of significance was set at $\alpha = .05$, and the magnitude of the treatment effect was interpreted using partial eta squared.

Before implementation, the learning devices and research instruments were examined by three experts, consistent with expert-validation procedures used in recent IJPES instructional-media research (Siregar et al., 2026). The components reviewed included the learning model, semester learning plan, learning material book, lecturer guide, student guide, practicality instrument, and model effectiveness instrument. Content validity was analyzed using Aiken's V, while the intraclass correlation coefficient was used to describe the level of agreement among validators. Aiken's V values ranged from .83 to .89, indicating that the reviewed components had good content validity. ICC values were interpreted carefully as evidence of inter-rater agreement rather than as a direct indicator of content validity.

The main tool used to evaluate students' learning outcomes was a 50-question multiple choice test, given as a pre-test and also as a post-test after training. One point was assigned to each correct response and zero points given when the answer was wrong. To ensure the content of the test was all-encompassing, the exam was created based on a detailed test blueprint. It reflects and is in harmony with the Pharmacology and Doping curriculum indicators on the one hand, and on the other, the exam was also reviewed by experts who gave it their seal of approval. The validity of each question was checked via Pearson product-moment correlation by calculating the correlation between the item scores and the total test score. This process was carried out with the help of SPSS for statistical analysis. An item will be considered valid if the resulting correlation coefficient exceeds the critical value of $r=.361$ for a sample size $n=30$,

significance level= α =.05. Item analysis, which involved determining the association coefficient of each item, showed that all of the 50 questions were valid. On the other hand, reliability analysis was able to generate a Cronbach's alpha value of .788. This is a pretty reasonable value for internal consistency given the context of students' learning outcomes assessment.

Table 1. Summary of Content Validity of Learning Devices and Instruments

Validated component	Experts	Mean score	Aiken's V	ICC	Interpretation
Learning model	3	4.36	.84	.664	Valid; moderate agreement
Semester learning plan	3	4.33	.83	.503	Valid; moderate agreement
Learning material book	3	4.45	.86	.255	Valid; low agreement
Lecturer guide	3	4.57	.89	.482	Valid; low-to-moderate agreement
Student guide	3	4.46	.86	.255	Valid; low agreement
Model practicality instrument	3	4.38	.85	.577	Valid; moderate agreement

Table 2. Summary of Validity and Reliability of Instruments

Component	Valid indicators/items	Experts	Reliability coefficient	Description
Learning model	28 of 34 indicators	3	.956	Reliable
Semester learning plan	17 of 18 indicators	3	.984	Reliable
Learning material book	16 of 18 indicators	3	.790	Reliable
Lecturer guide	11 of 13 indicators	3	.911	Reliable
Student guide	11 of 13 indicators	3	.790	Reliable
Model practicality instrument	26 of 27 indicators	3	.947	Reliable
Pretest and posttest	50 of 50 items	-	.788	Reliable

Results

Descriptive Statistics and Pretest Equivalence

As presented in Table 3, the descriptive results indicated that the two groups had similar pretest performance before the intervention. The conventional classroom group obtained a mean pretest score of 13.87 with a standard deviation of 4.24. The web-based flipped classroom group obtained a mean pretest score of 14.60 with a standard deviation of 5.64. After the intervention, the conventional classroom group obtained a mean posttest score of 28.40 with a

standard deviation of 5.77, while the web-based flipped classroom group obtained a mean posttest score of 36.93 with a standard deviation of 6.45.

The pretest equivalence test showed no statistically significant difference between the two groups, $t(28) = -0.402$, $p = .690$. This result suggests that the students in both groups started the intervention with relatively comparable initial ability. Nevertheless, the pretest score was retained as a covariate because initial ability was theoretically and empirically related to posttest achievement.

Table 3. Descriptive Statistics of Pretest and Posttest Scores

Group	N	Mean pretest	Pretest SD	Mean posttest	Posttest SD
Conventional classroom	15	13.87	4.24	28.40	5.77
Web-based flipped classroom	15	14.60	5.64	36.93	6.45

ANCOVA Assumption Tests

The correlation analysis showed that pretest scores were significantly related to posttest scores. In the conventional classroom group, the correlation was $r = .674$, $p = .006$. In the web-based flipped classroom group, the correlation was $r = .651$, $p = .009$. Across all participants, the correlation between pretest and posttest scores was $r = .576$, $p = .001$. These findings supported the use of the pretest score as a covariate.

The Shapiro-Wilk test indicated that the residuals were normally distributed, $p = .751$. Levene's test showed that the assumption of homogeneity of variance was met, $p = .687$. The interaction between learning model and pretest score was not statistically significant, $F(1, 26) = 0.211$, $p = .650$, indicating that the homogeneity of regression slopes assumption was satisfied. Overall, the main assumptions required for ANCOVA were met.

Table 4. Summary of ANCOVA Assumption Tests

Assumption	Test result	Significance value	Decision
Residual normality	Shapiro-Wilk	.751	Satisfied
Homogeneity of variance	Levene's test	.687	Satisfied
Relationship between covariate and posttest score	Pearson correlation	.001	Satisfied
Homogeneity of regression slopes	Model x pretest score	.650	Satisfied

ANCOVA Results and Adjusted Means

The ANCOVA results demonstrated that the learning model had a statistically significant effect on students' posttest scores after pretest scores were controlled, $F(1, 27) = 21.344$, $p < .001$, partial eta squared = .442. The covariate also had a significant relationship with posttest performance, $F(1, 27) = 20.584$, $p < .001$, partial eta squared = .433.

The partial eta squared value of .442 indicates a large treatment effect in the observed class context. After adjustment at the overall pretest mean of 14.23, the conventional classroom group had an adjusted posttest mean of 28.70, whereas the web-based flipped classroom group had an adjusted posttest mean of 36.64. Thus, after controlling for initial ability, students in the

flipped classroom group achieved higher learning outcomes than students in the conventional classroom group.

Table 5. ANCOVA Results

Source of variation	df	F	Sig.	Partial eta squared
Learning model	1	21.344	< .001	.442
Pretest score	1	20.584	< .001	.433
Error	27			

Table 6. Adjusted Mean Posttest Scores

Group	Adjusted mean posttest score
Conventional classroom	28.70
Web-based flipped classroom	36.64

Discussion

The results show that the web-based flipped classroom improved students' achievement in the Pharmacology and Doping course. The experimental group obtained a higher posttest mean than the control group, and the difference remained significant after adjusting for pretest scores. This finding indicates that the higher achievement of the flipped classroom group was not merely a consequence of initial ability differences. Rather, it was associated with the different structure of learning activities experienced by the students.

The use of ANCOVA strengthened the interpretation of the results. In educational experiments conducted in intact classes, students rarely begin with identical prior knowledge. Comparing posttest scores without adjustment may overestimate or underestimate the effect of an intervention. By statistically controlling for pretest variation, ANCOVA produces an estimate of the learning model's effect that is more suitable for a pretest-posttest quasi-experimental design. This analytical decision is consistent with methodological discussions that emphasize the importance of accounting for covariates when evaluating group differences in two-wave data (Jung et al., 2025; Köhler et al., 2020; Lüdtke & Robitzsch, 2025).

The effectiveness of the web-based flipped classroom can be understood through the redistribution of learning time. In conventional instruction, classroom sessions often prioritize the lecturer's explanation of core content, while exercises and deeper reflection occur after class with limited immediate support. In the flipped classroom, students first encounter basic materials through the LMS. This restructuring shifts the initial processing of factual content to a self-paced, learner-controlled setting, which reduces the cognitive load associated with absorbing new content and taking notes at the same time during class (Oudbier et al., 2022). Because foundational knowledge is already available before the session, class time can instead be devoted to retrieval practice, case-based elaboration, and immediate feedback on students' reasoning, mechanisms that are more strongly associated with durable learning gains than passive exposure to lecture content (Baig & Yadegaridehkordi, 2023; Park et al., 2021), a pattern also observed for digital learning media in other Indonesian sport-education contexts (Putri et al., 2026). This structure gives students more opportunities to transform factual knowledge into applied understanding.

The findings are in line with previous evidence on flipped learning. Meta-analytic evidence across disciplines reported positive effects of flipped classrooms on student performance (Strelan et al., 2020), while Van Alten et al. (2019) showed that achievement gains

are more likely when pre-class resources are intentionally connected to in-class activities. In health professional education, [Hew and Lo \(2018\)](#) and [Naing et al. \(2023\)](#) similarly reported favorable learning outcomes. More recent medical education synthesis by [Spaic et al. \(2025\)](#) supports the potential benefit of the approach, while also indicating substantial contextual variation. The present study contributes a sport science course context in which pharmacology knowledge must be connected with doping prevention and athlete safety.

The result is also supported by evidence from pharmacology and pharmacy education, which is the closest disciplinary comparison for the present course. [Wu et al. \(2022\)](#) found that micro-video supported flipped pharmacology teaching produced higher theory test scores and more favorable student feedback than traditional instruction. [Jaiprakash \(2022\)](#) reported significant knowledge gains and positive perceptions after online-tool-supported flipped pharmacology sessions, whereas [Sajjad and Gowani \(2021\)](#) demonstrated the feasibility of introducing the approach in a pharmacology course for nursing students. At the synthesis level, [Cui et al. \(2023\)](#) reported improved student learning in pharmacy education, and [Gondal et al. \(2024\)](#) documented improved academic performance and satisfaction in a quasi-experimental pharmacy education study. [Onódi et al. \(2025\)](#) extended this evidence by focusing on knowledge retention in pharmacology. Collectively, these studies strengthen the interpretation that the present finding is consistent with a course area in which factual drug knowledge benefits from guided application and retrieval-oriented activity.

From a pedagogical perspective, the intervention's effect should not be attributed to the LMS alone. The relevant mechanism is the planned sequence of preparation, activation, feedback, and consolidation. In this study, modules, videos, quizzes, and learning notes prepared students for classroom case discussion, while reflective assignments and online forums continued the learning process after meetings. This interpretation is consistent with [Oudbier et al. \(2022\)](#), [Park et al. \(2021\)](#), and [Baig and Yadegaridehkordi \(2023\)](#), who highlight the importance of constructive alignment, active in-class work, and meaningful post-class follow-up in flipped designs.

A considerable partial eta squared value deserves both genuine curiosity and prudent caution. After all, a small quasi-experimental study of 30 students cannot provide definitive evidence one way or another. However, this result still represents a significant practical change in the students' experience in their regular course of study. Therefore, we should look at it as promising contextual evidence, not a definite statement that the same results will be produced in every other context.

The flipped method is best explained when the course background is in the context of it. In 'Pharmacology and Doping', a content-rich subject, students are first taught complex material and then asked to use that in solving real-world issues faced by athletes. At every opportunity to learn, the students are required to identify the distinction between prescription medicine and non-prescription use, learn potential drug side effects, and make an overall risk assessment between supplements and medicines. Also, they are expected to bring the concepts of pharmacology together with ethics and antidoping laws in sport. The part of reading in between the classes is used by students to acquire basic knowledge of what will be discussed in the class and to be able to use it in analyzing an athlete's case, to discuss options with an emphasis on safety, and to provide well-founded decisions supported by the relevant regulations. That well-thought-out flow of events suits perfectly the educational goals that combine a high standard of science together with the awareness of the legal side and ethical aspects. Besides the higher test scores as shown in the figures, this way of teaching could promote achievements beyond those recorded by tests alone. That is students who can make well-founded regulatory decisions, give reasoned justification for choices, and take a classroom discussion to the application of that decision in real-life situations is a very valuable ability that athletes are advised on when they are considering risks of doping. Such capacities are at the

core of anti-doping literacy and professional skill development regardless of not being assessed in the conventional post-test multiple-choice question type.

Anti-doping education is also an important element of this study's novelty. The International Standard for Education positions education as a required component of the global anti-doping program, while the current Prohibited List identifies substances and methods prohibited in sport (Agency, 2021, 2026b). The ADEL platform further demonstrates that anti-doping learning can be provided through accessible online resources (Agency, 2026a). Empirical studies give this curriculum emphasis a strong rationale: Sepriani et al. (2023) identified a substantial need for web-based anti-doping education among achievement-sport athletes in Indonesia; García-Martí et al. (2022) reported improvements after an online anti-doping education program for sport sciences students; Hurst et al. (2023) observed reduced doping susceptibility following a national education program; and Nicholls et al. (2025) concluded that university anti-doping education is promising but requires more robust intervention designs. Consequently, Pharmacology and Doping learning should extend beyond memorizing drug categories toward interpreting rules, evaluating medication and supplement risks, and making responsible clean-sport decisions.

The study's main contribution through the research design is a very systematic and thorough validation procedure of the measurement instruments before implementing the intervention. Besides, the instruments proved to have great face validity in accordance with the resources used in the education and the methods employed in the final assessment-as indicated by Aiken's V values - they were also found highly dependable upon re-administration of the achievement test. A commonly held opinion is that the success of an experiment is primarily determined by the sophistication of the design of the intervention; nevertheless, using measurement and data collection instruments that are characterized by high reliability and validity is equally, if not more, important. It goes without saying that to achieve trustworthy results, one must ensure the precision and the authenticity of the instruments used. Therefore, thorough validation of an instrument is crucial. A study of this kind should therefore not be interpreted solely from the point of view of the ICC figures, but the results themselves have to be properly contextualized and evaluated. A moderate or low rating of an ICC doesn't mean a learning measure is invalid, but rather that there is some level of disagreement among the validators over certain aspects of the item, which is also common in learning materials. A learning environment that uses the flipped classroom strategy at its core should be viewed as an integrated educational model, going beyond the idea of only having students watch videos at home.

To really work, this teaching method relies on a clear weekly schedule for the students' learning; brief, well-constructed materials that go with the video content and the students have access to the whole materials anytime; and frequent checks, like quizzes to gauge preparation and participation. It has been shown that having forums where students can freely discuss their thoughts about the topics together with the presentation in classes by the students on what they have learned are excellent ways for interaction. For example, a case study about "anti-doping" which is one of the ways learning through students' own problems can be implemented is another very good example of students' involvement with such a learning model. Through this method, students are not only given an excellent opportunity for deep discussions about the risks of drug use, but also are enabled to examine drug side effects and the whole drug use problem in different contexts which might lead to a deeper understanding. In addition, they are provided with a variety of materials from different sources and the ones especially recommended and officially approved by anti-doping agencies can be very useful for students. At the same time, the teachers or lecturers should play a major role of guidance and monitoring. It is their responsibility to ensure that besides the students watching videos at their homes, they will be able to prepare themselves properly and give a feedback that would connect

the remote and the face-to-face parts of the education. Without such coordination and integration, flipped classroom models will simply remain as digital learning projects which are the only part of the educational experience offered, thus they fail to represent the vision of these models which is about having a teaching and learning context enriched with features.

This study has several limitations. First, the sample size was small, so generalization should be made cautiously. Second, the study was limited to one course and one study program. Third, the study focused on cognitive achievement and did not examine motivation, engagement, satisfaction, digital literacy, critical thinking, clean-sport values, or attitudes toward anti-doping in depth. Fourth, LMS activity data such as login frequency, video completion, quiz attempts, and forum participation were not analyzed as explanatory variables. Finally, the study did not assess longer-term retention or application of anti-doping decision making, outcomes that are relevant in light of pharmacology learning research and recent anti-doping education evaluations (Hurst et al., 2023; Nicholls et al., 2025; Onódi et al., 2025). Future studies should involve larger samples, multiple classes or institutions, longer follow-up, and mixed-method or learning-analytics data so that the mechanisms behind flipped classroom effectiveness can be understood more comprehensively.

Conclusions

The web-based flipped classroom model was more effective than conventional classroom instruction in improving students' learning achievement in the Pharmacology and Doping course, even after students' initial ability was statistically controlled. This finding indicates that the higher achievement observed in the flipped classroom group reflects a genuine effect of the learning design rather than pre-existing differences between the two groups.

These results indicate that a learning design combining LMS-based independent preparation, case-oriented classroom activity, and post-class reflection can improve students' cognitive achievement. The main contribution of the study lies in applying the web-based flipped classroom to a course that requires mastery of pharmacological concepts, understanding of athlete health risks, anti-doping regulatory literacy, and sport case analysis.

In terms of practicality, sport science degree courses may well be able to incorporate such results as a general guide to develop LMS-based learning among different levels, from very basic concepts to more elaborate thinking and reasoning.

We recommend further studies that go beyond single class or institution level, cover larger and more varied target groups, and link up LMS activities such as login statistics, video views, quiz attempts and forum participation with outcomes as predictive variables.

In addition, the longer term effectiveness of anti-doping and pharmaceutical education should be studied through a mixed methods approach involving interviews and questionnaires which could capture the students' motivation, level of engagement, knowledge of information and communication technologies and their opinion about drug-free sport.

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Conflict of interest

The authors declare that there are no conflicts of interest related to the publication of this article.

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