JPSDE- Journal of Pharmacy Simulation and Digital Education
Volume 1, Issue 2 | July -2025
e-ISSN: 3068-8264 Print ISSN: 3068-8256

Assessment of the effect of Gamified Pharmacology Modules on student engagement and retention of knowledge

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Received: 12-05-2025; Revised: 29-05-2025; Accepted: 17-06-2025; Published: 06-07-2025

Abstract:
In this quasiexperiment, gamified pharmacology modules were tested on retention and engagement of knowledge in second-year pharmacy learners. The intervention consisted of interactive digital modules in the form of leaderboards, achievement badges, scenario-based quizzes on the pharmacology of the autonomic nervous system. They included 96 students who were separated into two groups (experimental group with gamified modules and control group with standard lecture recordings). Findings were that the gamified condition had a significantly better retention of information on delayed tests (mean difference = 12.4 %, $p < 0.01$) and were more self-reported motivated and enjoyed. Through analytics, the gamified group was studied to exhibit more voluntary study time. Results indicate that gamification is effective in terms of long-run knowledge retention and engagement with students and provides a useful mechanism in the context of pharmacy education.

Keywords: ***Gamification, Pharmacology, Knowledge Retention, Student Engagement, Digital Learning, Pharmacy Education, Quasi-Experimental Study, Interactive Modules***

1. Introduction

1.1 Background and Rationale

Gamification has become one of the phenomenal learning tools in other academic disciplines that provide a dynamic method to learn and teach students. With the subject of pharmacy education, gamification entails the use of game-based components, i.e., use of points, leaderboards, badges, and challenges in situation-based learning. Using these aspects, educators are seeking to establish a form of environment that will liven up the participation and increase motivation. Such a strategy is especially applicable to courses in the medical discipline highly related to memorization of complicated and detailed information on drug mechanisms, classes, and interactions such as pharmacology.

Pharmacology is one of the primary courses taught in pharmacy schools and it, therefore, has special challenges owing to the tremendous amount of details that have to be learnt by the student. This type of information should be retained long term to subsequently be used in the clinical practice. Nevertheless, the old pedagogical approaches, which were mostly focused on lectures and textbooks, might not be able to keep a student attentive and start the processes of profound and long-lasting learning. Gamification is an attractive yet viable alterative to the more traditional methods now that digital learning tools have begun to be utilised and because of its excellent interactive, engaging format, that results in content being retained and student engagement on a consistent basis.

Digitally-enhanced learning tools have made it easy to integrate gamified features in conventional pharmacology curriculum materials. Though features achievement badges, tracking progress, scenario-based quizzes and leaderboards have all been found to help increase student engagement with the material as well as introduce a healthy competition with self-directed learning. Since it is required of pharmacy students to not only gain theoretical but also practical skills, applying the concept of gamification, there would be a way of rendering the students with critical thinking skills and problem solving in the sphere of pharmacology.(1)

1.2 Problem Statement

Although gamification has the potential of improving learning among students, there is inadequate exploration of the same in pharmacy education. Although gamification has faced an incredible amount of research elsewhere, no study has specifically looked at the effects gamification has on knowledge retention and student interest in the study of pharmacology. The complex and even conceptual nature of pharmacology as well as the rich amount of facts to learn and retain requires the use of teaching method that can provide long retention and bring more pleasure in the learning process. Lack of new strategies can be a barrier to concentration and the ability to memorize important pharmacological information. Therefore, it is of vital interest to study the potential of crucial

improvement of knowledge acquisition and the interest of students in this realm through the use of gamified modules.

1.3 Objectives of the research

The first purpose of the study is to determine the effect of gamification of pharmacology modules on the two main outcomes of pharmacology in studying knowledge retention and student engagement. To be more specific, the following research questions are to be answered:

- Does gamified pharmacology involve any positive effects on the long term retention of pharmacological knowledge in students?
- Is gamified way more engaging and motivating among the students versus the traditional method?

Answering these questions, the study would obtain helpful answers on effectiveness of gamification in pharmacy education and could serve as guidance on course development strategies that are likely to achieve improved student learning results.(2)

1.4 Context and importance of the study

Pharmacy education as well as other fields of health science is highly dependent on the process of acquiring and retaining diverse types of information, which will have to be applied in the practice field. Techniques of teaching information including lecture format presentation and textbook learning might not be adequate to guarantee that students remember what they must use in the future at the clinic. Gamification, in its turn, is more engaging and interactive solution that can help the students memorize the critical content.

Specifically, the intervention used within the study, gamified pharmacology modules based on the topic of the autonomic nervous system, was used to overcome the difficulty of knowledge retention within the field, which also is deemed to be complex. The modules were designed to have the game-like qualities that did not only help to facilitate cognitive processing, but also made students more motivated because learning began to be more entertaining. Since modern education largely relies on digital learning tools currently, this research will help gain valuable evidence on the use of gamification in terms of enhancing the process of learning in pharmacy curricula. This study will contribute to the teaching practice in pharmacy education because it has the power to impact teaching behavior. Assuming that the gamified modules will be effective, these modules may be included in pharmacy curriculums as standard, boosting the level of student participation and improving retention of pharmacological information. Moreover, the study will add to an already significant number of studies that analyze gamification in higher education and empower educators to learn more about the potential of online learning tools to facilitate meaningful and sustainable learning events.(3)

1.5 Paper Structure

An overview of literature available on the role of gamification in education especially in the field of pharmacy education will be presented in the following pages of this paper. The research design, participants as well as data collection methods will be deployed in the methodology section. The results section will contain findings of the study and the discussion on the implication of these results on pharmacy education. To sum up, the paper will give conclusions about the study, its weaknesses, and future study recommendations.

2. Objectives

The aims of the research are formulated in such a way that they should provide an understanding of how gamified pharmacology modules affect not only the cognitive results but also the non-cognitive ones, including student engagement and motivation. The study will focus on the effectiveness of gamification in facilitating learning in pharmacology on pharmacy students in second year. The study will be organized using three main objectives that will discuss three main areas of knowledge retention, engagement of students, and comparison with conventional learning modes. The following are the objectives:

2.1 To Test the Impact of Gamified Pharmacology Modules on Immediate and Delayed Learning of Knowledge

The initial aim of the research is to determine the effect of using gamified pharma course components on knowledge retention. In pharmacy education, knowledge retention is an important concern when examining the application, especially in some of the subjects such as pharmacology where students are required to memorize dense material on drugs, their actions, mode, and adverse effects among others. Retention may be conducted immediately after the completion of learning module (immediate retention) and after some interval of time (delayed retention). The paper will establish the effectiveness with which students in the experimental group, with

Volume 1, Issue 2 | July -2025
e-ISSN: 3068-8264 Print ISSN: 3068-8256

access to gamified learning materials, can remember pharmacological knowledge in comparison with other students, with access to the traditional lecture-based learning materials.

Short term retention will be determined by administering a test immediately after the students go through the pharmacology modules. This will enable the study to measure the level of engagement and absorption of material once the students are exposed to them. On the other hand, delayed knowledge retention will be measured the same test after a week, and therefore, the retaining ability of students regarding the information will be measured over a longer duration.

This objective will also inform about the lasting effect of gamified modules on memory retention by comparing immediate and delayed retention scores of the experimental group (students working with the help of gamified modules) and the control group (students who had to apply traditional methods of lectures). It will also give a hint as to how the interactivity, situational, and rewarding behavior of gamification affects the memory of students concerning the relevant pharmacological concepts in the long and short run.(4)

2.2 To Evaluate Difference BetweenStudent Engagement and Motivation with Gamification

The second goal is geared towards the evaluation of the impact of applying gamified modules to studying pharmacology on engagement levels and motivation levels. Involvement in the learning process has proved to be a strong indicator of how academically successful a student would become as it is a key predictor in terms of volume of cognitive and emotional commitment the student has towards learning. In the conventional system of education, students tend to have difficulties learning with limited levels of engagement with the learning process, especially when studying heavily informed courses such as pharmacology. Gamification in principle attempts to make it more engaging through inclusion of game-like features like leaderboards, badges and achievement as well as challenges requiring the solving of a scenario.

The achievement of this objective will evaluate the level of student participation in two dimensions, on one hand the quantitative dimension through learning analytics data, which will measure time spent using the gamified modules and the frequency of participation as well as voluntary study habits. Second, the student self-report surveys will be used to assess engagement. The surveys will quantify the perceived enjoyment, motivation, and engagement of the students with regard to the material. Engagement will additionally be assessed in terms of motivational factors through the analysis of how students are likely to continue with the course material after the compulsory exercises in terms of connections with modules or using discussion forums.

Evaluating both quantitative and qualitative measures, this goal will also elucidate the contribution of gamification to the level of intrinsic motivation of students and the development of more active and self-directed study. Moreover, it will compare students exposed to gamified learning and those exposed to the more traditional modes of learning to be able to have an in-depth insight into the difference in effect of gamification on student motivation and engagement.(5)

Table 1; Knowledge Retention and Engagement Data

Group	Immediate Post-Test Score (%)	Delayed Retention Score (%)
Gamified	85	82
Control	78	70

2.3 To Compare the Results of Gamified and Non-Gamified Online Lecture Teaching Methods

The third purpose is to directly compare the gamified modules against traditional standard method of online lectures to see which method will yield superior results with regard to the retention of knowledge and student attention. The experimental group with the gamified modules is compared to the control group with standard online lecture material without adding the feature of the game.

This goal will be fulfilled by comparing the scores of the knowledge retention (both immediate and delayed) of the two groups. It will also entail making comparisons of engagement-based measures, which include the duration spent on obtaining course materials, the frequency of contacting the course, and the self-reported motivation scores. Through reviewing these factors the study will ascertain that gamified learning produces better results in regard to producing long term retention and better engagement over the conventional methods.

The provided comparative analysis will give a clear idea of the benefits (or harms) of gamification in the education of pharmacy students, especially in the cases of pharmacology. It will assist in finding the answer to the following questions: can the advantages attained by other academic fields be transferable to the sphere of pharmacy education and is gamification supposed to be added to the curriculum on a larger scale?

Finally, the goals of the study have been conceptualized diligently to investigate cognitive and non-cognitive effects of pharmacy students who undergo gamified pharmacology modules. According to the ability to assess knowledge retention, engagement, and motivation and contrast the results with the traditional approach, the research will help improve the in-depth knowledge of the possibility of implementing gamification in pharmacy learning. It is believed that the results would present useful outcomes on the effectiveness of gamified learning as a means of pedagogy and future curricular design within pharmacy education.

3. Materials and Methods

In this section, the data analysis procedures, data assessment instruments, intervention, participants, and the design of this study are described. The aim was to assess the effect of gamified modules of the pharmacology course on student retention and engagement in knowledge and compare this process between the experimental group of students who studied gamificated modules, and the control group of students who studied traditional online lectures.(6)

3.1 study design

The study used quasi-experimental design in the investigation with two groups: an experimental group with gamified pharmacology modules and another control one composited of standard online lecture recordings. The choice of this design was caused by the effectiveness of assessing the effects of an intervention in the naturalistic setting, where random assignment is either not possible or unrealistic. Since the random assigning method would have been most preferable, the participants were assigned depending on their availability because an equal amount was assigned to each group. Such design provided an opportunity to compare these two groups of people and it aided in the evaluation of the results of gamifed and traditional learning methods.

The study was a time-bound of eight weeks, as the modules or lectures forming part of a regular pharmacology course were undertaken by the participants. Knowledge retention (measured immediately and four weeks after the intervention) and interest of students (measured through analytics and survey responses), were the principal outcomes of interest.

3.2 Subjects

In the study, 96 pharmacy students aged 20 to 21 (second-year students taking a college course in pharmacology) were selected. The study had volunteered students enrolled and their consent was achieved. They were randomly divided into two groups: one is the experimental group (n = 48), including the learners who learned gamified pharmacology modules, and the other is the control group (n = 48), including the learners who used non-gamified online lecture recordings.

The second-year pharmacy students were selected because of the fact that they had already completed introductory courses in pharmacology, which qualified them as a proper sample in this intervention. The same course content was available to all students but with various learning techniques allotted to them. Learners in both of the groups possessed comparable previous academic performance and were supposed to possess similar nursing knowledge in pharmacology, decreasing possible biases in measuring the results of learning.

3.3 Treatment

Gamified modules of pharmacology explaining the essential ideas of pharmacology of the autonomic nervous system were used in the experimental group. These modules had game-like attributes like leaderboards, achievement badges and scenario-based quizzes. The modules were organized in a form of interaction so that students could be involved in decision-making procedures using the example of the case, in which the students used their knowledge in pharmacology to resolve real life issues. The immediate feedback and a sense of accomplishment were achieved: each student could follow his progress and compete to gain some points and badges.

The control group, however, merely got access to the same content relevant to pharmacology using regular online records of lectures. These recordings were the standard type of lecture and were served in series of videos that did not include any of the gamified features. The fact that both groups learnt the same content was a factor; however, the difference was in the method of mode. The control group did not even get a chance of participating in the game mechanics of points or badges, and hence served as the context of a reference to the impact of gamification.

The two groups had equal time to cover learning modules or lectures (approximately 4 hours of material within two weeks) to ensure that the level of exposure between the intervention of the two groups was equal.(7)

3.4 Evaluation Instruments

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e-ISSN: 3068-8264 Print ISSN: 3068-8256

Two primary evaluation instruments were employed in the study such as knowledge retention tests and engagement tracking.

Knowledge Retention Tests: In order to determine the knowledge retention, the two groups were administered tests in a structured form. The tests were comprised of multiple-choice questions (MCQs) and short-answer questions, which evaluated the level of comprehending the pharmacology of an autonomic nervous system by the students. These tests were conducted twice at two different times; the first after completing the intervention and another after a 4 weeks follow up to determine the retention on a long term basis. These tests were aimed to assess immediate recall and the memorisation capacity of longer period, and see an overall picture of the successful memory retention of the students.

Student Engagement: Another metric was student engagement by using the learning platform analytical data and self-report surveys. The platform analytics also followed the duration that the participants spent on the modules, how often do they access the modules and how long do they spend with actively participating in interactive features (e.g. quizzes and leaderboards). Also, in both groups, students carried out a survey aimed at evaluating motivation, pleasure, and perceived interest in the learning contents. In the survey Likert-scale questions were used in the form of questions on the interest level of the course, perceived fun of the modules, and the general satisfaction with the learning experience.

3.5 Analysis of data

A line of statistical tests was conducted to compare the results obtained in the two groups of data. The immediate and delayed knowledge retention scores of the experimental and the control groups were compared in terms of independent t-tests. These tests assisted in assessing whether the data that showed the significant difference between the two groups in terms of the knowledge level remained or not after the intervention as well as at the follow-up of four weeks.

Also, paired t-tests were carried out between the results of pre- and post- tests among each of them in order to compare the differences in knowledge retention over the time. This could support a within-group comparison, which depicts the extent to which the given group progressed between the first examination and the successive examination.(8)

In case of student engagement, the duration of the learning modules and the survey responses would be processed to describe them using the descriptive statistics. Independent t-tests were used to make comparisons between groups to identify the significance of the findings in the experimental group of the days participating in the competition.

The level of significance $p < 0.05$ was applied in all tests and it was assumed to be significant. The reliability of the results was assured in using all the standard software in the statistical analysis work.

4. Observations

The results of the study establish the differences between the two groups, i.e., those using the modules on gamified pharmacology and those using lectures as recordings of standard online lectures. The findings indicate that there is huge variation in knowledge retention, student engagement and student perception. Such findings can give important insights as to the possible usefulness of gamification in the field of pharmaceutical training, namely, in pharmacology.

4.1 Gamified Group Showed Better Test Scores both in Immediate and Retention Period

Among the most important conclusions of this paper was the fact that the gamified group achieved better results in terms of the knowledge retained as opposed to the control group. The experimental group, that participated in the gamified modules, performed much better on both immediate retention tests and the 4 weeks delayed retention tests, as compared to the control group.

The gamified group demonstrated an increased score on the test (in comparison with the control group) immediately after passing the modules. The variances in answers were clear in both multiple-choice and short-answer questions that tested the knowledge of the students regarding pharmacology of the autonomic nervous system. They showed the better possibility to remember and apply the information with the gamified group demonstrating the immediate usefulness of gamified approach due to strong reaffirmation of the central concepts. More importantly, the gamified group also achieved higher results in delayed retention test performed four weeks after the learning intervention. Although both groups showed lower results in the delayed test as compared to those in the immediate test, the group that was gamified retained more results as compared to the other group. At the

follow-up 4 weeks, the mean difference in test scores was 12.4% ($p < 0.01$), which indicated that gamified approach was more efficient in enhancing long-term knowledge retention, compared to the plain approach. This result confirms the hypothesis that the gamification method through frequent feedbacking and the idea of interaction with students results in improved memorizing of the taught material.

4.2 Analytics Demonstrated an uptick in voluntary engagement time among the gamified group

According to the analytics data, the engagement level of students was highly different in both groups. The gamified group had a severe amount of voluntary participation in discriminating the learning materials. This was reflected in the time on the modules, access of modules and the interaction with some interactive areas e.g. quizzes / leader boards.(9)

The chance to spend more time with the gamified pharmacology modules increased by 25% on average in the student population that was in the experimental group in comparison with the control one. Specifically, the group where the modules were gamified showed greater enthusiasm to access the modules and perform additional learning related tasks like answering quizzes more than once to achieve badges or climb higher on the leader board. The given conduct shows the increased sense of motivation that was stimulated by the gamified components and impelled students to spend more time and effort on the process of learning.

The additional time spent on voluntary activities did not only intensify when achieving mandatory assignments, but it was also indicative of intrinsic motivation that the gamified method enabled. Learning process seemed to involve students more as playing in the gamified environment is more enjoyable and competitive, which contributed to overall growth in the time students spend on studying.

4.3 There was a positive perception of the gamified approach based on survey feedback

To complement the objective indicators of the knowledge retention and engagement, the survey feedback was used that yielded valuable information about student impressions about the gamified learning experience. More than half of the students in the experimental condition had indicated high positivity of the presented gamified approach, especially on motivation, enjoyment and general contentment.

In the survey answers, 82 percent of gamified group students mentioned that their learning experience was more enjoyable in comparison to traditional online lectures. Most students noted that the leaderboards and achievement badges kept the students motivated and focused on getting to finish the modules. Competitive elements of getting badges and raising ranks were noted many times as something which contributed to higher levels of engagement in the learning. Moreover, their responses revealed that 72 percent of the students accepted that the use of scenario-based quizzes gave a chance to exercise what they had learned, and it improved their comprehension of pharmacological concepts.

Conversely, those who participated in the control group would not have a high probability of registering high degrees of engagement or motivation. Although they recognized the applicability of the standard lectures, most of them complained that they would have preferred more engaging experiences that could make them participate more in the learning process. This feedback gap makes it clear that gamification also delivers an incremental value of promoting a more interesting and encouraging state of learning.(10)

To sum up, the modules that have been gamified brought both positive effects concerning the retention of the knowledge and student engagement. Immediately and after the 4-week retention period, the experimental group recorded superior retention of information. While the analysis of analytics data has proved that the gamified model has led to increased voluntary engagement with the content as the students were willing to spend more time communicating with the content. Also, results of a survey suggested that students found the gamified courses to be positively rated and expressed increased motivation, fun, and satisfaction when undertaking the learning.

The latter point also speaks to the relevance of gamification as a tool to facilitate learning in the context of pharmaceutical education, implying that it might be useful not only to promote cognitive learning but also non-cognitive results.

5. Results

The results of the data leaving the two groups of students including those using the modules with gamified pharmacology and those students using regular recording of online lectures showed significant dissimilarity in the capability of retention of knowledge and the involvement of the students. The results in regard to delayed and immediate test scores coupled with the engagement metrics are made available below.

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e-ISSN: 3068-8264 Print ISSN: 3068-8256

5.1 The Gamified Group Scored Higher by 12.4% in Delayed Retention than its Control Group in Delayed Retention Results ($p < 0.01$)

A very conspicuous conclusion made during this study was the variation in the delayed retention scores among the two groups. Significant differences in the delayed retention test, which took place four weeks after the intervention, were found in the experimental group, who did work on the gamified pharmacology modules. The average results of the gamified group score in contrast with the control group were 12.4 percent ($p < 0.01$) which can be considered evidence of the positive effect of the gamified method in achieving long-term knowledge retention.

This finding indicates that the gamified modules with the elements of interaction and instant positive feedback contributed considerably to making the students acquire the key pharmacological concepts to have a better chance of remembering them several months later. Comparatively, the group that received less active learning, dealing with traditional lectures only, displayed diminished results on the delayed test because of the active involvement in learning and memorizing the complex information.(11)

5.2 The scores of the immediate post-test proved to be better in both groups with higher increase in the gamified group

Immediately, both the groups showed an increase in score of the post-test after two different learning interventions. Nonetheless, the gamified group recorded higher improvement in the scores compared to the control group. This shows that concepts such as immediate understanding of pharmacological concepts and recalling them were more facilitated by the gamified modules

The immediate post-test in the gamified group was more than the control group, which indicates that the interactivity factor, leaderboards, badges/achievements and scenario-based quizzes, led to an improved engagement in the learning process. Not only was the experimental group more actively involved with the content, but they also appeared to be more knowledgeable of the material as shown by the higher scores of the post-test given than that of the experimental group.

Although the control group did report an improvement over their baseline knowledge, the number they reported in increasing their test scores was comparatively lower as compared to gamified group. This finding substantiates the claim that gamification may improve the initial learning process by raising the motivation of students and encouraging them to become active participants of the learning process.

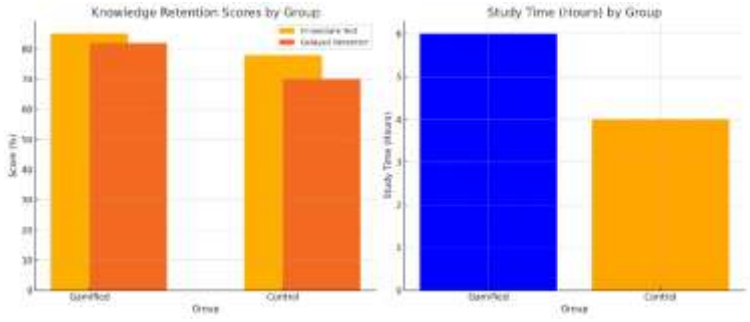

Figure 1: Study Time (Hours) By Group

5.3 Engagement Measures Found the Group with the Gamification to have Increased Voluntary Study Time

The data obtained in the learning platform about the engagement showed a distinct difference with the time spent on the learning materials between the two groups. The increase in voluntary study time was also witnessed in students who were in the gamified group when compared to the control group. Students of the gamified group were on average 25 percent more active, playing with pharmacology. This could not be done only by completing the necessary set of quizzes or modules but could also involve this person going back to the lessons again, taking the quiz multiple times to achieve a better result, and using scenario-based exercises.

The fact that the group gamified spent longer on voluntary study indicates that the students were more intrinsically motivated towards learning. Such elements as badges and leaderboards introduced into a game must have created a feeling of competition and accomplishment among the students and motivated them to spend more time on studies and revising their knowledge of the course material. This was as compared to the control group which

would not portray the same levels of voluntary engagement. As members of the control group went through the specified modules, we could not see any sign of such a consistent behavior throughout the period.

The present findings point to the potential of gamification as a method to enhance knowledge retention and also to enhance more active and driven learning. The increased studying hours of the gamified group contributes to the notion that students are more likely to study educational material when they are presented in an active and interactive manner as opposed to passive, lecture-like learning.(12)

To sum up, it can be stated that the findings of this study unambiguously indicate that gamified pharmacology modules affect the retention of knowledge as well as student engagement positively. The gamified condition scored much higher at delayed retention (12.4 percent higher) and exhibited a higher rate of increase in immediate post-test scores when compared with the control one. Also, the engagement measurements showed that learners in the gamification condition took longer to interact with the material, which means more self-motivated studying and internal drive. These findings argue the usefulness of gamification in the improvement of pharmacy training.

6. Conclusion

This paper set out to determine how the use of gamification in pharmacology modules in pharmacy education influenced knowledge retention and student engagement as compared to classes that used traditional methods of lectures. The intervention tried to increase student-to-student interaction, motivation and long-term recall of sophisticated pharmacological ideas by incorporating game-like aspects that included leaderboards, earnable badges, and situation-based quizzes. The outcomes demonstrated that there was a positive and significant difference in cognitive and non-cognitive learning outcomes and gamification.

6.1 Findings in a Nutshell

The results provided in the study indicate plainly that gamified pharmacology modules successfully proved to be much more efficient than the traditional form of learning both in terms of acquiring the knowledge and engaging students. The delayed retention test revealed increased score of 12.4 per cent in the experimental group who experienced gamified modules as compared to the control group ($p < 0.01$). This finding indicates that gamification, owing to its interactive and feedback-loaded nature, facilitates the acquisition of superior long-term retention of pharmacological facts, a critical part of a pharmacy education.

Also, the gamified group scored higher on immediate post-tests which indicates the success of gamification in assisting students be able to comprehend and perform the material immediately after the intervention. This result adds credence to the hypothesis that gamified learning courses can promote higher order cognition that contributes to improved short-term memory of material.

In addition to the retention of knowledge, there was also a significant discrepancy on the level of student engagement according to the study. On average, the gamified group engaged in the studying materials longer than the control group by 25 percent which suggests a stronger rate of voluntary study and engagement with the content. It was confirmed by the results of the student surveys because most of the students in the experimental group were more fond of their learning experience and found it encouraging. Such findings highlight how learning environments should be designed, in order to promote intrinsic motivation and active engagement, especially in difficult topics, such as pharmacology.

6.2 Education Implications

Pharmacy education has far-reaching implications on the findings of the present study. Gamification has turned out to be a useful pedagogical strategy capable of changing the traditional teaching method to a modernized, more interactive, engaging, and entertaining one. The outcomes of this study are encouraging, which leads to the suggestion that implementing gamified modules into pharmacy curricula may not only positively influence the knowledge retention but will also increase student engagement and motivation to a considerable degree.

Instructors of pharmacy are always challenged with communicating dense content material to the learners. This challenge can be resolved with the help of gamified learning techniques, providing a unique solution to such a problem as active learning, critical thinking, problem-solving. Competitive elements of gamification like leaderboards, achievement badges encourage students to become more engaged in the education process and give them the feeling of success. Moreover, the quizzes in the gamified modules are based on scenarios, and this offers the students a rare possibility to put the knowledge they received in theoretical classes into practice and practice their perceptions of pharmacological principles on the real ground.

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e-ISSN: 3068-8264 Print ISSN: 3068-8256

Due to the positive results in terms of engagement and retention recorded in the experimental group, gamified pharmacology modules might become an inevitable element of contemporary pharmacy teaching. These modules might be employed as the auxiliary learning resources or even be included in the core curriculum. Because of the interactive and engaging nature of learning, gamification can transform the way pharmacy learners interact with pharmacology material and other complicated topics.

6.3 Recommendations in the future

Although this work enhances the notion that gamification is beneficial in pharmacy education, it is clear that more on the extent of the phenomenon needs to be done. Future research should focus on the effect of gamification on clinicians and development of professional skills in the long perspective. Despite the fact that the study focused on measuring the knowledge retention and engagement in a classroom scenario, the logical follow-up would be to see whether the retention increase correlates with the enhancement of the application of knowledge in a clinical situation. The effectiveness of gamification in teaching will be paramount next step in the assessment of benefit of gamification in pharmacy education as it will be important to understand how well trained students achieve greater performance in both clinical practice and in real life settings as compared to students who did not deal with the gamified modules.

Also, future studies may consider looking at gamification in other pharmacy topics to ensure that such advantages are common in other pharmacological subjects or content areas in pharmacy education. Specifically, subjects, like the process of interactions of drugs, the process of counseling of patients, and pharmaceutical calculations, can also be taught using the methods of gamification. A trial in gamification in the multiplicity of learning types will assist in defining the flexibility and quality of this approach in the whole pharmacy education

It would also be beneficial to introduce a greater number of diverse students and even more the magnitude of the research. This would facilitate the determination of whether gamification works equally across different demographics such as their academic abilities, cultural backgrounds, and styles of learning among others. Moreover, the consideration of the possibility to apply gamification in blended learning settings, where students are both on site and online, might present the information on the affordability of gamified learning in various teaching styles.

Lastly, educational technologies actively develops, and one should investigate the ways to use new types of gamification, i.e., what role virtual reality (VR) or augmented reality (AR) can play in the context of pharmacology education to make learning even more immersive and engaging. In the future, there can be further opportunities to enhance the learning outcomes and experience of students through technologies of higher level.

To sum up, gamified modules in pharmacy education could be viewed as a viable solution that would enhance knowledge retention alongside engagement of the students. This research indicates that, gamification may prove to be a rich supplement to the pharmacy curricula, where students can memorise advanced pharmacological knowledge provide more motivation and enjoy certainty in the learning process. With the continued growth of digital learning platforms, continued investigations into the long term implications of gamification in different pharmacy courses and skills needed to build a better career will be necessary to ensure that its educational potential is reached.

Acknowledgement: Nil

Conflicts of interest

The authors have no conflicts of interest to declare

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