Design and Evaluation of a Gamified E-Learning System for Remedial Mathematics in Pharmaceutical Education

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Abstract: With the recent decline in university students' academic abilities, many pharmaceutical sciences students in Japan have resulted in many lacking fundamental high school-level mathematics skills, making effective remedial education increasingly essential. Traditional methods often fail to maintain motivation, leading to poor outcomes. To address this, we developed a gamified e-learning tool with interactive content and progress tracking, targeting key math concepts in pharmaceutical education. Formative evaluations showed improved motivation and retention across various academic levels. Students reported that the tool lowered their anxiety toward math and promoted consistent learning. These results suggest that this kind of gamification is a promising strategy to support foundational education in specialized fields.

1. Introduction

The declining academic proficiency of university entrants has prompted many institutions in Japan to implement remedial education (Ishikura, 2008). Students of pharmaceutical sciences must quickly master high school-level math and chemistry, often using e-learning for self-study. However, students with low confidence tend to avoid self-directed learning, making motivation a key factor. LMS enhancements, like Asai et al.'s praise-based Moodle module, have shown limited impact on encouraging continued practice (Asai, 2017).

2. Development of the E-Learning System

At A University, where the author is affiliated, interviews suggested that students struggled with deep understanding, particularly in exponential and logarithmic functions, as formula-based instruction lacked conceptual clarity, thereby diminishing their motivation to learn. According to the gamification theory, learners are more motivated when they experience the joy of discovery (Saito, 2013). This study developed a gamified e-learning system to improve engagement and learning outcomes in remedial education of exponential and logarithmic functions. Our system was designed to allow students to discover mathematical formulas for themselves, thus deepening their understanding and increasing engagement. Another key principle of gamification is the visualization of progress, which helps learners objectively assess their situation and build confidence (Kapp, 2017). The content on exponential and logarithmic functions was divided into short, manageable units. Each unit included the element of 'recall learning'—a gamified feature—to help learners recall prior knowledge and connect it with new problems, thus reinforcing understanding and motivation.

The LMS platform used was Moodle 4.2, enhanced with plugins (Watson, 2023) to allow access via both PC and smartphone. Upon logging in, learners enter a main screen displaying all available exercises, including the final test, in a sequential layout. Each exercise takes approximately five minutes, allowing for low-burden study during short periods. As shown in Figure 1, a progress pie chart grows as learners complete exercises, visualizing their journey toward completion. Additionally, learner performance is ranked on the main screen, allowing students to track their improvements and foster confidence through repetition.

Figure 1. Visual Indicator of Learning Progress on the Dashboard.

3. Formative Evaluation and Effectiveness

The completed material was reviewed by a mathematics lecturer at A University, who acted as a subject matter expert (SME). The SME confirmed that the question content and instructional sequence based on the task analysis were appropriate and coherent. Formative evaluations were conducted with five first-year and one fourth-year pharmaceutical students. Pre-test scores showed around 50% proficiency in both exponential and logarithmic topics. Therefore, these five individuals were deemed suitable users of the material, and were subsequently asked to use it. After completing the material, post-test results exceeded 90% for all students, indicating that the tool was effective across multiple academic levels. Interviews conducted after the exercises indicated that students were able to internalize content more easily than through textbooks, while also experiencing reduced math anxiety and improved learning consistency. Access logs further revealed that students tended to complete multiple exercises in a single session, suggesting that the inclusion of gamification encouraged sustained engagement and promoted ongoing learning.

4. Conclusion

In this study, formative evaluations showed improved engagement and significant learning gains across student levels. Features like progress visualization encouraged repeated learning and deeper retention. These results suggest that this kind of gamified e-learning can effectively support foundational education across various academic levels.

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