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Evaluating the Effectiveness of a Gamified and NLP-Enhanced Adaptive Learning Platform for Engineering Education

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Abstract

Introduction

Traditional engineering education methods often struggle to maintain student engagement. This study presents a gamified learning platform leveraging natural language processing (NLP) to generate subject-specific problem sets, incorporating level-based challenges, streak tracking, and rewards to enhance motivation and learning outcomes.

Methods

The platform, developed using React Native for cross-device compatibility and leveraging the Moodle API from an existing learning management system, integrates FastAPI for backend operations. It employs a fine-tuned T5 model for question generation and a bidirectional encoder representations from transformers model for context-aware answers. The Leitner System and Bayesian Knowledge Tracing facilitate adaptive learning, while SQL and SQLAlchemy manage structured data. Key features include secure authentication, dynamic quizzes, progress tracking, and multimedia study resources, all built on top of the Moodle API to streamline course management and user data synchronization.

Results

Preliminary testing suggests improved student engagement and motivation through gamification. Streak tracking and level progression encourage consistent study habits, while NLP-driven adaptive assessments personalize learning.

Conclusion

The integration of gamification and NLP in educational platforms has the potential to transform engineering education by making learning more interactive and adaptive. This approach not only fosters consistent study habits but also strengthens problem-solving skills and overall academic performance. Future efforts will focus on expanding the platform to additional disciplines and conducting long-term evaluations to assess its impact on educational outcomes.

Categories: Software Development, User Experience (UX) Design, Natural Language Processing (NLP)
Keywords: student engagement, gamified, nlp, react native, adaptive learning, engineering education

Introduction

The digitization of education has revolutionized the way students access knowledge, offering unprecedented opportunities to enhance learning experiences through technological advancements [1,2]. One of the most transformative developments in this area is the incorporation of gamification, which refers to the integration of game-design elements such as points, levels, and rewards into non-gaming contexts [3,4]. Gamification in education has emerged as a powerful tool to engage students, motivate consistent learning, and make complex subjects more approachable [5,6]. Studies have shown that game elements such as challenges, leaderboards, and progress tracking significantly enhance student motivation and improve learning outcomes [7,8]. In this paper, we present a gamified mobile platform tailored specifically for engineering students, merging the principles of gamification with cutting-edge natural language processing (NLP) techniques [9,10]. By offering dynamic question generation using NLP, the platform ensures a diverse set of challenges, adapting to the varying skill levels of students as they progress through their courses [11,12].

A key feature of our platform is the Streak and Progress Calendar Page, which encourages students to develop consistent study habits by tracking their engagement over time. By maintaining daily streaks,

students stay motivated and committed to continuous learning. Prior research indicates that streak-based learning can increase intrinsic motivation and performance in students, making it an effective tool in gamified educational platforms [13,14]. In addition to gamified problem-solving, the platform offers Level-Based Challenges that guide students through progressively difficult stages, enhancing their problem-solving skills and making learning interactive. These challenges align with research findings that emphasize the impact of game-design elements on psychological need satisfaction and learning motivation [15,16].

To support academic success, the platform provides video tracks related to core engineering courses. Students can access these videos at any time, enabling self-paced learning and reinforcing key concepts through visual and auditory aids [17,18]. The integration of multimedia learning helps cater to different learning styles, making the platform more versatile and inclusive. Additionally, the Course Content Implementation Screen allows students to solve quizzes and questions according to their selected topics. These resources, including past-year question papers and academic notes, ensure that students have access to well-structured and relevant content [3,12].

With the increasing need for personalized and adaptive learning tools, this system aims to bridge the gap between traditional learning methods and modern educational demands by providing an engaging, user-friendly solution. By integrating gamification, NLP, and multimedia learning resources, we strive to make learning more dynamic, enjoyable, and effective, helping engineering students not only grasp core concepts but also retain knowledge over the long term.

Objectives

The primary objective of this study is to develop and evaluate a React Native mobile application that leverages adaptive gamification and NLP-driven question generation to address the challenges engineering students face in maintaining consistent study habits, achieving technical proficiency, and accessing organized academic resources [3,9,13]. Specifically, the app will incorporate level-based problem-solving challenges and daily streaks to foster competence, autonomy, and relatedness [3,14]; integrate a fine-tuned T5 model for dynamic, context-aware question generation to adapt to individual progress and enhance engagement [5,9]; embed curated semester notes and past-year question papers to streamline resource accessibility and support effective exam preparation [5,12,15]; and include video tracks for core engineering topics to cater to diverse learning styles and reinforce complex concepts [7,11]. By implementing these features, the study aims to determine whether the platform can significantly improve students' learning outcomes, intrinsic motivation, and consistent study behaviors compared to conventional instructional approaches.

Scope

The scope of this study encompassed the design, development, and empirical evaluation of a React Native mobile application for engineering students that integrates adaptive gamification and NLP-driven content generation to foster intrinsic motivation and improve learning outcomes [3,7,9,14]. The platform's core functionalities included level-based problem-solving challenges, daily streaks, and progress tracking-features specifically engineered to satisfy the psychological needs of competence, autonomy, and relatedness as defined by Self-Determination Theory (SDT) [3,14]. Educational materials such as curated semester notes and past-year exam papers were embedded to support exam preparation and reinforce conceptual understanding [5,12,15], while a fine-tuned T5 model generated context-aware questions dynamically, ensuring personalized learning paths [5,9]. The backend utilized MongoDB to store unstructured data (e.g., user profiles, authentication data, and generated content) for scalability and flexibility [11]. To assess the platform's effectiveness, students were divided into experimental and control groups: both groups completed pre- and post-tests, but only the experimental group engaged with the gamified, NLP-enhanced application. Learning improvements were evaluated via independent t-tests, and intrinsic motivation was measured using the Intrinsic Motivation Inventory (IMI)-based Psychological Needs Questionnaire. This comprehensive scope allowed us to demonstrate that the experimental group achieved significantly greater gains in post-test scores and reported higher levels of competence, autonomy, and relatedness, confirming that adaptive gamification and NLP-driven question generation effectively enhance knowledge retention, problem-solving skills, and sustained motivation in engineering education.

Background

Problem Statement

Engineering students often struggle to maintain consistent study habits when tackling technical subjects that require regular practice and deep understanding [3,9,13]. Traditional, lecture-based methods can be monotonous and fail to engage students, resulting in procrastination and knowledge gaps [5,10]. The complexity of engineering coursework demands frequent reinforcement, yet students lack interactive tools or personalized feedback to stay motivated [3,9]. Additionally, locating and organizing essential resources such as past-year exam papers and semester notes remains a significant barrier to effective

learning [4,12]. This study investigates whether a gamified, NLP-driven adaptive learning platform can enhance study consistency, motivation, and resource accessibility compared to conventional instructional approaches.

Objective of study

Literature Survey

While several educational platforms, such as Coursera and edX, offer a wealth of resources for engineering students, they often lack the gamification elements that significantly enhance user engagement and motivation [1,2]. These platforms primarily focus on delivering content through video lectures and assessments but do not provide the interactive, game-like experiences that can transform learning into a more enjoyable process [4]. Applications like Duolingo have successfully leveraged gamification to increase engagement in language learning [9]. However, while Duolingo excels in language acquisition, it does not specifically address the needs of engineering students or utilize advanced technologies like NLP for automatic question generation [4].

Our system addresses these gaps in the educational landscape by focusing on engineering students and offering the following features:

Gamified Learning Environment: By integrating level-wise challenges, students can progress through different stages of difficulty, similar to game levels. This structure promotes a sense of achievement and encourages consistent study habits [7].

Dynamic Content Generation Through NLP: Unlike traditional educational platforms, our application utilizes NLP techniques to automatically generate varied and relevant questions, providing a personalized learning experience that adapts to the student's progress and skill level [5,9].

Interactive Learning Features: Inspired by gamified platforms like Duolingo, our system incorporates elements such as streak tracking and rewards, incentivizing students to engage regularly and build consistent study habits [9].

Targeted Resources for Engineering Subjects: By combining gamification with a focus on engineering topics, our application ensures that students receive tailored content that meets their specific academic needs, addressing the shortcomings of existing platforms [2,4]. By merging these innovative approaches, our platform aims to create a more effective and engaging learning experience for engineering students, enhancing both their motivation and academic performance.

SDT, introduced by Ryan and Deci [19], explains the concept of intrinsic motivation in students, that is, the drive to engage in an activity purely for personal fulfillment rather than external rewards or pressure. According to SDT, when students are intrinsically motivated, they are more likely to engage deeply in tasks that interest them, which can lead to improved learning outcomes. The theory identifies three fundamental psychological needs that foster enjoyment and motivation: competence, autonomy, and relatedness [19]. Competence refers to the need for students to feel successful and confident in achieving their goals. Autonomy involves the need for a sense of freedom and control in making decisions. Relatedness reflects the desire for meaningful social connections. When these three needs are satisfied, students are more likely to internalize intrinsic motivation, which in turn enhances their engagement and overall learning performance.

Materials And Methods

Methodology

Study Design

The goal of this course is to teach the fundamentals of Database Management System (DBMS), including relational database concepts, SQL queries, normalization, indexing, and transaction management. EduTech offered a number of exercises and tests to gauge students' understanding. Nine game design components were incorporated into our EduTech specifically to meet the competence, autonomy, and relatedness, which are essential psychological needs identified in SDT (competence, autonomy, and relatedness) and boost students' motivation [19]. Table *1* lists the proposed components of the game design along with their relationship to the three psychological needs.

Needs	Game design element	Matching
Competence	Points	They provide prompt feedback on how well students are learning. This can help perform better and feel more capable while learning.
	Badges	
	Leaderboard	
	Progress bar	
	Feedback	
	Levels	
Autonomy	Avatar	They provide users the option to select the images or avatars that show up on their profiles and to choose whether or not to display the badges they have accumulated to other people.
	Badges	
Relatedness	Chat	It creates a feeling of accomplishment.

TABLE 1: Matching Game Design Elements With Psychological Needs

Participants

The study's trial involved 13 male and 19 female undergraduate students, for a total of 60 students. They were between the ages of 18 and 24 and were majoring in computer science. Participants were split into two groups at random: the experimental group and the control group (30 students each). The control group studied DBMS using a traditional educational technology (non-gamified version), whereas the experimental group used a gamified and self-determined educational technology to study the same.

Procedure

To find out what the students knew about DBMS, both groups performed a pre-test. Prior to utilizing the gamified and self-determined EduTech, the experimental group completed the Psychological Needs Questionnaire to gauge their degree of satisfaction with the three psychological needs. Following that, each group spends three months learning "DBMS" utilizing a particular EduTech version (traditional, and gamified and self-determined). To ensure consistency, the same teacher created the learning materials for both editions. The teacher gave a quick explanation of how each game design component functions in EduTech before beginning the gamified and self-determined EduTech. Eventually, both groups completed the post-test to assess the students' degree of learning performance following the three-month learning process. Additionally, after utilizing the gamified and self-determined learning environment, the experimental group completed the psychological needs questionnaire once more to gauge their level of satisfaction with the three psychological needs.

Methods

We first examined how the suggested game design components affected students' psychological requirements before evaluating how the gamified and self-determined setting affected their learning performance. Students' psychological needs -competence, autonomy, and relatedness - are evaluated using a psychological needs questionnaire. Three to four items drawn from IMI are included for each variable. For example, "I am satisfied with my performance at this course" is used to demonstrate competence, "I could make my own decisions while learning in this environment" to demonstrate autonomy, and "I felt like I was a part of a team while learning this course" to demonstrate relatedness. A 7-point Likert scale, with 1 denoting total disagreement and 7 denoting full agreement, was used to score each psychological requirement item. Cronbach's α was used to examine the instrument's reliability, and the results showed that the three variables (competence, autonomy, and relatedness) had acceptable reliability values (above 0.7) [16]. Based on the difference between the pre-and post-questionnaires, the degree to which students were satisfied with the three psychological demands was determined. Psychological needs' overall descriptive statistics are shown in Table *2*.

Psychological needs	Experimental group			
	Pre-questionnaire		Post-questionnaire	
	Mean	SD	Mean	SD
Competence	3.76	1.38	5.15	1.05
Autonomy	3.31	1.25	4.85	1.21
Relatedness	2.60	1.53	4.08	0.93

TABLE 2: Intrinsic Motivation Inventory Results

SD, Standard Deviation

Data Analysis

Table 2 indicates that students' post-questionnaire mean scores for relatedness, competence, and autonomy are greater than their pre-questionnaire mean scores. This demonstrates that, in the gamified and self-determined learning environment, the suggested game design components have met the psychological needs of the students. The mean values of the pre-and post-tests were then compared using the t-test method. According to the null hypothesis, the means of the students' scores do not significantly differ from one another. According to the alternative hypothesis, there is a difference in the average scores of the pupils.

Experiment

This study aimed to evaluate the effectiveness of a gamified learning platform integrated with NLP in improving student engagement and learning outcomes. A total of 60 undergraduate computer science students (aged 18-24) were randomly divided into two groups: an experimental group that used the gamified platform and a control group that followed a traditional e-learning approach. Both groups studied the same DBMS curriculum over three months.

At the start, all participants took a pre-test to assess their baseline DBMS knowledge. The experimental group also completed a Psychological Needs Questionnaire, based on IMI, to measure competence, autonomy, and relatedness. This was done to evaluate how the gamified platform influenced student motivation over time. During the learning phase, the experimental group interacted with a gamified platform featuring dynamically generated quizzes (using T5 and BERT models), level-based challenges, leaderboards, badges, and a streak tracking system. They also had access to structured study materials, multimedia resources, and past exam papers. In contrast, the control group used a conventional e-learning platform with static materials and standard quizzes. Both groups had the same instructor to ensure consistency.

After three months, participants completed a post-test to evaluate their learning progress. The experimental group also retook the IMI-based Psychological Needs Questionnaire to measure changes in motivation. Statistical analysis was conducted using t-tests to compare learning outcomes and engagement levels between the two groups. Cronbach's α was used to verify the reliability of questionnaire responses [16].

Results

The learning outcomes of the students in the traditional and gamified and self determined learning environment are shown in this section. The results obtained using the t-test method for the pre-test and post-test are shown in Tables 3 and 4, respectively. The p value (sig) must be less than 0.05 for a result to be deemed significant.

Table 3 indicates that there was no significant difference between the mean scores of students in the experimental and control groups, as indicated by the t-test results for the pre-tests, with p equal to 0.77 and greater than 0.05. As a result, the null hypothesis is accepted. This outcome is explained by the fact that students in both the experimental and control groups are novices in DBMS, which explains why their pre-test scores are identical.

Group	N	Mean	SD	T	Sig
Experimental	16	20.61	5.12	0.16	0.77
Control	16	20.82	3.19		

TABLE 3: Results of the T-Test Analysis for Pre-Test Data

SD, Standard Deviation

In contrast, Table *4* demonstrated that there is a clear distinction between the experimental and control groups in the post-tests since p is equal to 0.00 and lesser than 0.05. Specifically, the mean score of the experimental group was found to be greater than that of the control group. Consequently, the null hypothesis is disproved. This is made explicit via self-determined and gamified EduTech that has improved students' learning outcomes more than traditional EduTech. Consequently, compared to the control group, the experimental group's learning performance was significantly higher.

Group	N	Mean	SD	T	Sig
Experimental	16	29.54	2.98	7.71	0.00
Control	16	21.82	2.10		

TABLE 4: Results of the T-Test Analysis for Post-Test Data

SD, Standard Deviation

Discussion

Experimental analysis

This study assessed the impact of a self determined, gamified learning environment on student performance and motivation. A t-test was conducted to compare learning improvements, showing that while both the experimental and control groups demonstrated progress, the experimental group exhibited a significantly greater increase in post-test scores. This suggests that adaptive gamification and NLP-driven question generation contributed to better knowledge retention and problem solving skills. An independent t-test further confirmed that the experimental group outperformed the control group, reinforcing the effectiveness of game-based learning strategies.

The IMI-based Psychological Needs Questionnaire was used to assess engagement levels. Results revealed a significant increase in competence, autonomy, and relatedness among students in the experimental group, whereas the control group showed little to no change. This indicates that gamification elements such as level progression, rewards, and interactive engagement fostered sustained motivation and encouraged consistent learning behavior.

Intrinsic motivation and engagement

Using the IMI-based Psychological Needs Questionnaire, we measured changes in competence, autonomy, and relatedness. Students in the experimental group reported significant increases across all three dimensions, whereas the control group showed little to no change. These results indicate that gamification elements such as level progression, reward mechanisms, and interactive engagement successfully satisfied key psychological needs. In turn, this satisfaction fostered sustained motivation, encouraged more consistent learning behavior, and likely contributed to the superior performance measured in the experimental group.

Repercussions and implications

Resource Allocation: Institutions may need to reallocate resources such as instructional design support, software development budgets, and faculty training to support the adoption of such platforms. Investing in gamified, NLP-driven tools could yield long-term gains in student performance and retention, but requires initial infrastructure and development costs.

Scalability and Transferability: While this study focused on engineering students, the underlying model

(adaptive question generation and gamified mechanics) could be extended to other STEM fields or even non-technical disciplines. Stakeholders should evaluate whether similar motivational effects can be achieved in mathematics, natural sciences, or liberal arts courses.

Limitations

Sample and Context: The study was conducted with a relatively small sample of undergraduate engineering students at a single institution. As a result, generalizability to other universities, degree levels, or non-engineering populations is limited. Follow-up research should test the platform across diverse geographic and institutional contexts to confirm its broader applicability.

Short-Term Intervention: The intervention lasted only one academic term. Although performance gains and motivational improvements were evident, it remains unclear whether these effects persist over multiple semesters or translate into long-term knowledge retention. Longitudinal studies are needed to assess durability of learning gains.

Further developments

Longitudinal and Multi-Institutional Studies: Conducting extended studies over multiple semesters and across several universities will help determine whether the motivational and performance benefits observed here are sustained and reproducible in other educational environments.

Broader Disciplinary Applications: Adapt the platform for non-engineering domains (e.g., mathematics, biology, arts) to evaluate cross-disciplinary effectiveness. Adjusting gamification mechanics (for instance, narrative-based challenges in literature courses) may be necessary to maintain relevance across diverse subjects.

Peer Collaboration Features: Introduce social or collaborative elements such as team-based challenges, peer review of problem solutions, or discussion forums to leverage social relatedness further. Early qualitative feedback suggests that students might benefit from collaborative gamified tasks, which could foster deeper conceptual understanding through peer-to-peer interaction.

Conclusions

This research demonstrates that a self-determined, gamified learning environment augmented by NLP-driven question generation significantly improves engineering students' learning outcomes and intrinsic motivation compared to traditional instructional methods. Experimental results show that students who used the platform achieved higher post-test scores, indicating better knowledge retention and problem-solving skills. Furthermore, increased self-reported competence, autonomy, and relatedness suggest that gamification features effectively meet fundamental psychological needs, leading to sustained engagement. While promising, these findings are tempered by limitations related to sample size, study duration, and reliance on self-report measures. Future work should explore long-term efficacy, broader disciplinary applications, and deeper personalization through advanced analytics. Overall, integrating adaptive gamification and NLP technologies offers a viable pathway to transform engineering education by fostering consistent study habits, enhanced motivation, and more effective learning experiences.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Siddhesh V. Thakarkar, Vikrant A. Agaskar, Prathmesh S. Tiwari, Mohak R. Tamore

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Disclosures

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