The Infusion of Gamification in Promoting Chemical Engineering Laboratory Classes

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Active learning strategies are increasingly implemented in chemical engineering education, yet challenges persist in stimulating student participation and motivation. The rigorous demands placed on students in this field, from complex practical requirements to extensive programming and computational skills, underscore the need for innovative educational tools. Gamification emerges as a pivotal instrument in this context, fostering active student engagement, enhancing practical application of knowledge, increasing motivation, and providing a more precise assessment of student comprehension. These educational games serve as a powerful adjunct to traditional teaching strategies, equipping students with necessary skills for their future careers in the field. These games include laboratory course games, process simulators, games used in foundational courses, and those centered around reaction kinetics. This entry primarily investigates the various games employed to bolster student learning during chemical engineering laboratory courses. A thorough analysis is conducted on the survey of existing games used specifically in chemical engineering labs. The gamut of games discussed includes escape games, along with Virtual Reality (VR) and Augmented Reality (AR) games, all aiming to enhance laboratory experiences in areas such as fluid mechanics, organic reactions, and process control. This entry concludes by examining the prospective trajectory of gamification in chemical engineering labs, offering insights into future potential and advancements in this innovative educational approach.

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1. Introduction

The training and education of engineers, especially chemical engineers, is constantly evolving. In recent years, there has been a transition from in-person to remote modes of teaching to cope with COVID-19-enforced restrictions. Also, the rapid transformation of chemical industries towards digitalization and automation have influenced teaching approaches in higher institutions [1]. Most of the changes are implemented in order to prepare students to actively participate in the transition to industry 4.0 (smart manufacturing) in today's world.

While adapting to these changes, educators are faced with difficult issues such as a lack of student motivation, a lack of flexibility in course syllabi, low student grades, burn-out due to increasing practical course requirements, and a lack of participation from students during class activities. Teaching through active learning has been suggested by some researchers as a method to improve the participation of students during classroom activities [2].

Active learning is a teaching method that involves actively engaging students with the course material through strategies such as problem solving, demonstrations, discussions, case studies, and role playing.

Khan et al. [3] reported that active learning is a great teaching mechanism for supporting student engagement. Another study showed that structured, live problem-solving sessions after students watch a pre-recorded lecture helped improve their participation in the classroom [4]. The authors noted that active learning helped remote students to engage more with the course materials. Due to the implementation of active learning, students are likely to come to class and participate and there are fewer class withdrawals from at-risk students. Despite the implementation of different active learning strategies, a lack of student participation and motivation is still a critical issue in chemical engineering education. Rigorous practical requirements, programming knowledge, and extensive computational skills are some of the demands that chemical engineering students face over the years.

Gamification is an important tool in chemical engineering education because it enables students to actively engage in their own learning, apply their knowledge in practical contexts, increase engagement and motivation, and it enables teachers to more accurately assess student understanding. It can be a useful supplement to conventional teaching strategies and helps to prepare students for careers in the field. Gamification is the implementation of different techniques adopted from game elements (from board to computer games) to achieve specific teaching goals. It is the use of game-designed elements in non- gaming settings. Gamification is often implemented to engage and motivate people and increase their involvement in different forms of activities, especially in non-gaming contexts. There are three main parts of gamification, such as the game elements, designing techniques, and the context in which the games are designed [5]. The latter is often unrelated to the games, but relates to the reason or objectives of the game. The design techniques describe different methods adopted in the games to increase the involvement and motivation of players, while the game elements refer to different components used in gamification.

Studies have shown that gamification can be applied in several fields for motivating and improving the participation of individuals. Narasareddy et al. [6] presented a systematic review of different areas where gamification could be applied in computer science education. They identified several game-design elements and their influence in improving computer-science-student motivation and class participation. Another study presented an overview of gamification applications in Massive Open Online Courses (MOOCs). The authors stated that gamification could help resolve the challenges of low completion rates in MOOCs by enhancing students' motivation and increasing completion rates [7]. Ahmed et al. [8] stated that gamification could also be used to improve learning and student engagement in medical education. The University of Washington also released a game known as "Foldit". Through the game, the public was asked to play a protein-folding exercise to clarify the structures of different proteins. Within 10 days of playing time, the players were able to unlock the crystal structure of a monomeric retroviral protease that causes AIDS in rhesus monkeys, a major challenge puzzle that most scientists had struggled to solve in 15 years [9]. This shows the successful application of gamification in education and scientific research.

Gamification is becoming increasingly important as a tool to enhance the learning experience and improve student engagement in chemical engineering education. One of the main advantages of gamification in chemical

engineering education is that it allows students to actively participate in their own learning process. Games provide a hands-on, interactive approach that allows students to experiment and make mistakes in a safe environment. This allows them to build a deeper understanding of the concepts they are learning and retain that knowledge more effectively.

The implementation of educational games in chemical engineering education allows students to apply their knowledge in real-world scenarios. Students have the chance to hone their problem-solving and decision-making skills in a realistic environment by playing games that imitate industrial processes or plant operations. Students are better able to comprehend the real-world applications of the principles they are studying thanks to this, which also gets them ready for careers in the sector.

Gamification also helps to improve student engagement and motivation. Games are inherently fun and engaging, and by using game elements in the classroom, educators can create a more dynamic and interactive learning environment. This can lead to increased participation and interest from students and can help to improve their attitude towards learning. Moreover, gamification can also be used to evaluate the understanding of students in a more effective way. Compared with traditional forms of assessment like multiple-choice questionnaires, games offer a more comprehensive assessment of student understanding by allowing them to demonstrate their knowledge and skills in a real-world setting [10]. Burkey et al. [11] developed a collaborative team-based game that helped improve student attitudes to learning during the senior capstone chemical engineering laboratory course. Despite the increasing interest in and implementation of gamification in chemical engineering education, most of the studies are scattered in the literature. Moreover, a detailed review of different games applied in chemical engineering education is scarcely reported in the literature. To fill the knowledge gaps, the present entry presents a critical review of games used to foster creativity and improve student participation in chemical engineering laboratory classes. An overview of the status and progress of gamification in chemical engineering education specifically for promoting student engagement during laboratory courses is also critically discussed.

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