 doi:10.20944/preprints202205.0196.v1

Article

Gamification In Chemical Engineering: A Research Study

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Abstract: One of the main effects of the digital transformation is that e-learning methodologies have become an inseparable part of the standard classes in schools and universities, mainly due to the current COVID-19 situation. In this way, several pedagogical methodologies should be implemented at universities, promoting students' motivation and outcomes learning. This research study analyses the implementation of gamification pedagogical strategy on 50-60 undergraduate chemical engineering students at the university by evaluating its effect on the success rate on a specific topic of Chemical Reactions Engineering subject and the motivation effect. Our results show a significant increase in the success ratio (25-30 %) with an apparent motivation effect. Therefore, it is mandatory to analyze more case studies such as the one presented here to understand better the use of these pedagogical methods and strategies in university.

Keywords: gamification methodology; teaching methodologies; high education

1. Introduction

In 1991, Charles Bonwell et al. [1] pointed out that active learning enhances student learning and improves student performance during classes and assignments. This type of learning includes numerous strategies and teaching methods that promote student participation and engagement with the material provided during lectures productively. Currently, several pedagogical methodologies have been already in use in high education to promote the learning and motivation of students [2-8].

Some of these pedagogical methodologies are also applicable in e-learning, which is one of the most visible digital transformation results in educational sciences, derived from the fourth industrial revolution [9]. E-learning is an Information and Communication Technologies based methodology. During the last years, this methodology, considered an additional strategy complementary to traditional learning, became the only reliable teaching method during the COVID-19 pandemic [10], when face-to-face lectures could not be afforded. That explains the high development of e-learning techniques during the last two years [11].

Gamification can be considered the most exciting and popular pedagogical methodology for students [12-14]. The gamification teaching method is in Aldrich's category of learning methodologies, which means learning by doing, practicing, or experimenting by playing games [15]. The gamification method has been defined as a continuous procedure of improving learning ability with motivational affordances to invoke gameplay experiences and achievements [16-18]. In the university field, it is referred to as the loss of interest and decreasing students' stress that reduces learning outcomes and understanding derived from the traditional way of teaching [19].

Nowadays, several platforms and educational tools offer an easy gamification implementation at all education levels. "Kahoot!" is among the most used and well-known among teachers. This platform allows an easy implementing questionnaire of the class routine [20], incorporating game mechanics, dynamics, and framework in the normal development of a class. There are several studies related to gamification, but this number of studies decreases in the case of technical sciences as engineering careers. In this work, we

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have implemented "Kahoot!" to gamify chemical engineering concepts, mainly to learn about basic concepts of engineering chemical reactors.

2. Methodology

2.1. Participants and Focus of the Research

The study samples were 50-60 students (43% women and 57% men) of Chemical Reactions Engineering (ratio of students during this research study), one of the main subjects of the third year of the Chemical Engineering university degree. Gamification was implemented in the first topic about basic concepts of chemical engineering reactors.

The implementation of gamification was evaluated through three academic years, i.e., 2018-219, 2019-2020 and 2020-2021. During the academic year 2018-19, the students were evaluated using a standard written questionnaire (control group). Students were evaluated using the "Kahoot!" questionary during the next academic years.The first academic year (2018-19) was considered the control group. Thus, comparing the success ratio between the control group and the following years, the effect of gamification on this subject was evaluated.

2.2. Gamification process. Design of questionaries

As described before, gamification was implemented in the first topic focused on chemical engineering basic operations, chemical reactions kinetics and its industrial application. This topic was chosen due to its high content of basic concepts and definitions, the key to understanding the subject's topics related to chemical reactions design. Moreover, it is one of the students' favourites, so the gamification implementation might significantly affect students' motivation.

Using the "Kahoot!", a questionnaire was created to evaluate this specific topic of the subject with two kinds of questions, i.e., multiple-choice and True-or-False. This application is easy and intuitive to use. Nevertheless, it will not be explained in detail in the present paper because it is out of its scope. In the "Kahoot!" platform, the questions can be designed in several ways (multiple-choice, true-or-false, short description, and others). A figure accompanies each question to ensure the understanding of the question by the students. Moreover, each answer is defined with a colour and a geometric figure, allowing the students to distinguish the answers accurately.

The questionnaire consisted of 20 Multiple-choice questions and 3 True-or-False questions for this gamification study. In the case of True-or-False questions, they were focused on the subject's learning outcomes, which the students should understand to succeed in the subject. The questions were prepared according to the lectures provided to students. The students had 60-120 seconds per question. **Error! Reference source not found.** provides the main information related to the questionaries design and gamification process.

Table 1. Questionaries design for gamification.

Data	Description
Subject	Chemical Reaction Engineering
Topic	Chemical Reactions to Industrial Scale (topic 1 of 7)
Questionnaire structure	20 Multiple-choice questions 3 True-or-False questions
Time per question	60 seconds – True-or-False 120 seconds – Multiple-choice
Academic years of the study	2018-19 / 2019-20 / 2020-21*
Control group (standard evaluation)	2018-19
Gamification implementation	2019-20 / 2020-21

**COVID-19 pandemic situation*

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2.3. Data Analysis and evaluation

The "Kahoot!" application can process real-time questionaries. Students were connected online with their users for the same session and performed the exam in the classroom. The students receive points for the correct answers, taking into account the used time for answering. In the background, this gamification tool also allows an evaluation of students' marks, records previous questionaries, and performs reports for educational purposes.

3. Results and Discussion

3.1. Effect of gamification on the success ratio

This subject evaluates the continuous works of the students through each topic. As part of this evaluation, several questionaries and exercises are carried out for each topic. The success ratio has been determined considering the students with a mark from 5.0 to 10.0, regarding the students' total. **Error! Reference source not found.** shows the success ratio of topic 1 of the subject, matter of the gamification.

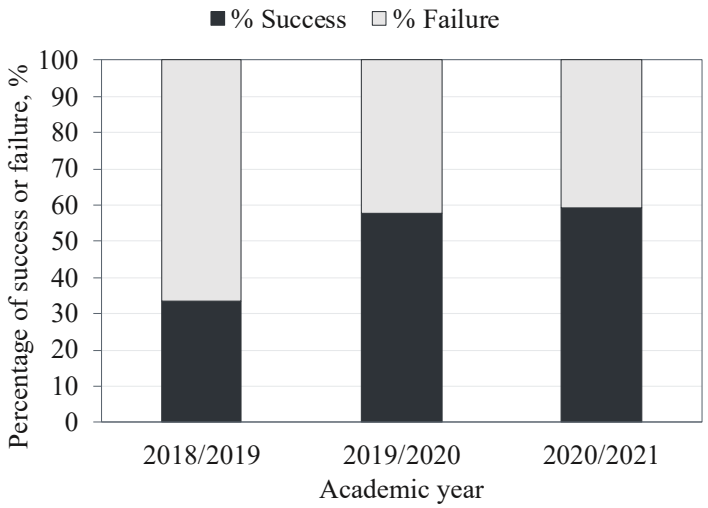

Figure 1. Success and failure ratio of the topic with and without gamification. "control group": 2018-19 and Gamification implementation: 2019-20 and 2020-21.

As it can be seen in the results, gamification implementation significantly increased the success ratio of the topic under evaluation, i.e., the percentage of students who succeeded during the evaluation of the topic related to basic concepts of chemical reactions engineering. This increase was up to 25-30% during the first year of gamification (2019-20) and was maintained during the following year (2020-21). This result is according to the expected, based on studies available on references [21].

As described in the methodology, the questionnaire was structured using two kinds of questions, "Multiple-choice" and "True-or-False". The True-or-False questions were used to evaluate the most critical points of the topics, which directly related to the learning outcomes. In this sense, **Error! Reference source not found.** shows the success and failure ratio of True-or-False questions used in this questionnaire.

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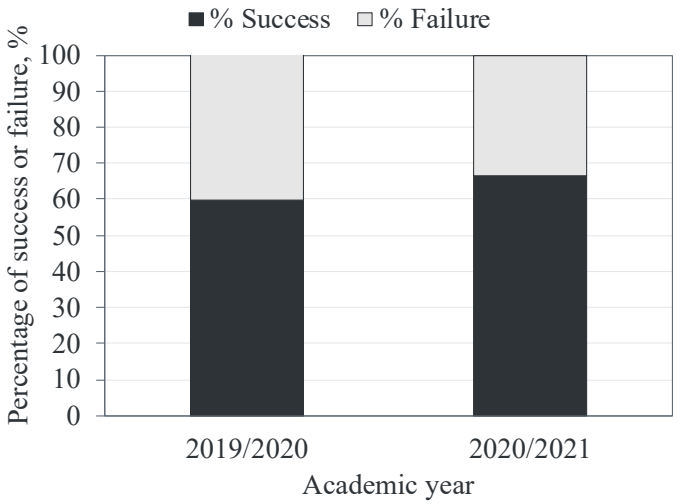

Figure 2. Success and failure ratio of learning outcomes understanding based on True-or-False questions. Gamification implementation: 2019-20 and 2020-21; COVID-19 pandemic: 2020-21.

According to these results, it is possible to claim that gamification implementation increases the ratio of success of the topic when it is applied. It is also related to a better understanding of the learning outcomes of this topic. This particular topic is critical in the subject structure, so a general increase of the learning outcomes understanding can also be expected for the rest of the topics of the subject. The incidence of the pandemic in the world society last year makes it unclear if the slight increase from 2019-20 to 2020-21 was only due to gamification or the COVID-19 pandemic situation, which affected the lifestyle of students during lockdown [22,23].

3.2. Effect of gamification on the student motivation

Gamification has an apparent motivational effect on student behaviour and interest in learning, as indicates several studies related to this pedagogical strategy and similars [24-27]. This fact is also supported by the data of this research study, observing a positive effect of gamification on the success ratio and learning outcomes understanding. In this sense, the "Kahoot!" application also provides a student's ranking with trophies, which is expected to motivate their outcomes learning in the following topics.

Based on subject structure, **Error! Reference source not found.** shows a suggestion of topic distribution with its description and the consideration for gamification to keep the motivation for learning in the rest of the topic of the subject. This schema is expected to be applied in the following academic years of the subject.

Table 2. Gamification plan for following academic years.

Topic	Gamification plan
Chemical Reactions to Industrial Scale	Gamification implemented
Homogeneous kinetics	Pending*
Homogeneous reactors. Simple reaction	Academic year 2021-22
Homogeneous reactors. Multiple reactions	Academic year 2021-22
Non-ideal reactors	Pending*
Heterogeneous catalysts	Academic year 2021-22

*Depending on results of the next cicle of gamification

4. Conclusions

Gamification pedagogical methodology was implemented on a specific topic of the main subjects of the Chemical Engineering degree at university, Chemical reactions

Engineering. For this purpose, an online "Kahoot!" questionary was designed and used to evaluate students learning by evaluating the success ratio during a specific topic during three academic years, including the control group and two years of implementation. Gamification teaching strategy resulted in a significant increase up to 30% of the success ratio of students, with an apparent effect on learning outcomes understanding. Our results suggest the high potential of gamification for technical subjects, with a significant and promising impact on success ratios, which positively enhance student motivation and might support the complete learning outcomes understanding to afford the whole subject. This research study means to be a practical reference in gamification studies related to engineering, with a promising and ambitious implementation plan for the following academic years.

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 doi:10.20944/preprints202205.0196.v1