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# The use of gamification in xMOOCs about energy: Effects and predictive models for participants' learning

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Open access education has significantly grown in strength as a new way of fostering innovation in schools. Such is the case of massive open online courses (MOOCs), which have the added benefit of encouraging the democratisation of learning. In this sense, the Bi-National Laboratory on Smart Sustainable Energy Management and Technology Training between Mexico and the United States of America was launched with the purpose of trying MOOC technology and measuring its impact on the academic, business, and social sectors. Under this scenario, this study aimed to show the relationship between using gamification and level of performance in a MOOC on energy topics. The methodology was quantitative, using the course analytical data for socio-demographic information and predictive models. A total of 6246 participants enrolled in the MOOC and 1060 finished it. The results showed that participants aged between 20 and 50 had the highest completion rates in the gamified challenge; the higher academic degree, the more inclined participants were to solve the gamified challenge; and no such distinction exists by gender.

*Implications for practice or policy:*
- xMOOC participants' educational level determines the successful completion of challenge-based gamification.
- Challenge-based gamification is a useful strategy for xMOOC students' evaluation.
- It is important to focus on the challenges design, if the planned challenges are not up to the students' skills, the learning results could be detrimental.
- Gamification in xMOOCs promotes participants' engagement regardless of age, gender, or educational level.

*Keywords*: MOOCs, gamification in education, gamified challenge, higher education, teaching methods

## Introduction

In 2016, the National Council for Science and Technology, the Secretariat of Energy, and the Tecnologico de Monterrey launched in Mexico the Strategic Energy Initiative Project to develop energy reform, which aims to impact academic, business, and social communities in Mexico and Latin America, raising awareness through open innovation of sustainable energy options (Ramírez-Montoya & García-Peñalvo, 2018; Rincón-Flores, Ramírez-Montoya, & Mena, 2016a). The project, called Bi-National Laboratory on Smart Sustainable Energy Management and Technology Training, consists of 12 sub-projects (http://energialab.tec.mx/).

One of these sub-projects aims at interdisciplinary and collaborative innovation to teach energy sustainability through massive open online courses, also known as MOOCs. The sub-project developed MOOCs of the xMOOC type, which are characterised by being massive and self-directed. These last have

been criticised for their strong behavioralist emphasis (Chiappe-Laverde, Hine, & Martínez-Silva, 2015) and low average completion rates (Cabero, 2015). Also, in recent years various institutions around the world have been reluctant to include innovative pedagogical elements, such as gamification, because they can be difficult to implement (e.g., Chang & Wei, 2016; Kyewski & Krämer, 2018; Magaña-Valladares et al., 2016; Vaibhav & Gupta, 2015; Willems et al., 2014).

The online course developed within the framework of the Bi-National Laboratory on Smart Sustainable Energy Management and Technology Training project was explicitly designed to include innovative pedagogical elements such as augmented reality, remote laboratories, challenge-based learning, and gamification.

For this study, we focused on the gamification-based challenge methodology – more specifically, to prove whether the use of challenge-based gamification as an innovative pedagogical strategy in an xMOOC can be influenced by socio-demographic variables (educational level, age, and gender) and test the effects of using a gamified challenge in an online course with regard to the final assessment scores. The ultimate purpose was to test whether gamification in online teaching in MOOCs improves students' learning (García-Peñalvo, García de Figuerola, & Merlo, 2010).

According to Werbach and Hunter's model (2012), challenges are part of the mechanics element since they smoothly integrate elements of learning (Gustetic, Crusan, Rader, & Ortega, 2015; Hamari et al., 2016) and gamification. In the same vein, activities in a game environment were designed to enable participants to apply their learning through solving a challenge-based problem (Kyewski & Krämer, 2018; Rincón-Flores, Gallardo, & Fuente, 2018) of the xMOOC energy course in which they were participating.

## Literature review

### The role of MOOCs in education

The growth of the Internet era has transformed educational systems, enabling an increase in learning opportunities within and outside educational institutions (Gómez-Zermeño, 2017). This phenomenon has encouraged the development of open access education, as it provides an opportunity to improve the transference and dissemination of knowledge (García-Peñalvo, 2015; Ramírez-Montoya, 2015; Ramírez-Montoya, Mena, & Rodríguez-Arroyo, 2017) thanks to free access and the collaborative and interdisciplinary participation of various communities. MOOCs emerged from the open access and distance education movement (Ramírez-Montoya & García-Peñalvo, 2018). In 2011, Stanford University launched the first MOOC, "Introduction to Artificial Intelligence", in which over 160,000 people enrolled (Dennis, 2012). Ever since, MOOCs have grown exponentially in various universities around the world (Del Moral-Pérez & Villalustre-Martínez, 2015; Zhou, 2016). As a matter of fact, 2012 was officially called the Year of the MOOC (Chauhan, 2014).

MOOCs were created with the intention to universalise access to education and therefore promote the democratisation of education (UNESCO, 2013; Vázquez-Cano, López-Meneses, & Sarasola 2013). Also, this type of course represents a chance to create and develop both instructional design and teaching models (Fernández-Díaz, Rodríguez-Hoyos, & Calvo-Salvador, 2017; Hernández-Carranza, Romero-Corella, & Ramírez-Montoya, 2015). Furthermore, Aguaded-Gómez (2013) claims that MOOCs not only grant students free access to numerous educational resources but also foster interrelationships between people from all over the world. For instance, they are a plausible way to encourage staff training in the business sector since employees can take courses anywhere any time (Olsson, 2016). This results in an advantageous situation, in terms of time and costs, to both employees and businesses.

There are currently different types of MOOC, although they are broadly categorised into two groups: xMOOCs and cMOOCs. xMOOCs are self-guided and are based on interactive multimedia such as video and text, and employ a behaviourist approach (Sánchez-Vera, León-Urrutia, & Davis, 2015). Meanwhile, cMOOCs are based on connectivism, as they take advantage of social networks so that participants can communicate and collaborate through various online channels such as Twitter, blogs, wikis, and Facebook, (Siemens, 2005). The big difference between these two types of MOOCs is, cMOOCs focus on knowledge generation while xMOOCs focus on knowledge duplication (Siemens, 2013). There are efforts to create hybrid MOOC courses with the intention of combining the connectivity of cMOOCs and the rigid and

controlled structure of xMOOCs (Fidalgo-Blanco, Sein-Echaluce, & García-Peñalvo, 2016; García-Peñalvo, Fidalgo-Blanco, & Sein-Echaluce, 2018). Despite evidence that proves their benefits, it must be emphasised that many programs opt for one of them. The choice depends on the pedagogical design needs of each course, on the technological resources, and the scope (Méndez García, 2013; Ulrich & Nedelcu, 2015). In the case of the MOOC of this research, the platform was limited to massive and free courses. As a consequence, it had to be self-directed, so the design fit in with the xMOOC.

### Gamification in MOOCs

Despite xMOOCs having benefitted many people around the world, they have also been subject to criticism, mainly due to their behaviourist approach (Ping, 2013) resulting in lack of immediate feedback to students (Hone & El Said, 2016; Xing, Chen, Stein, & Marcinkowsky, 2016), boredom (Barak, Watted, & Haick, 2016; Hew, 2016), low completion rates (Bartolomé-Pina & Steffens, 2015), and difficulties in favouring the inclusion of different types of participants (Kahan, Tal, & Nachmias, 2017). Thus, many researchers support the idea of including gamification in the pedagogical design of xMOOCs since it leads to an increase in motivation, completion rate, and even learning (Alraimi, Zo, & Ciganek, 2014; Borrás-Gené, Martínez-Nuñez, & Fidalgo-Blanco, 2016; Freire, Martínez-Ortiz, Moreno-Ger, & Fernández-Manjón, 2015; Hew, Huang, Chu, & Chiu, 2016; Kaplan & Haenlein, 2016; Vaibhav & Gupta, 2015).

Gamification is an innovative educational strategy that borrows elements from games to be used in non-game contexts (Marín, 2015). Its purpose is to place students in scenarios or simulations in which they can overcome appealing challenges in order to increase their engagement and competitiveness (Villalustre-Martínez & Del Moral-Pérez, 2015). Gamification is a trend with a long history: for example, badges and ranks have been awarded in the military for centuries, and leaders from the former Soviet Union used game elements to reward soldiers' performance (Dicheva, Dichev, Agre, & Angelova, 2015). Gamification has extended to other sectors, such as businesses, marketing, health, and, in recent years, education. Companies such as Starbucks, Amazon, eBay, Heineken, and Nike have employed gamification to increase brand loyalty (Williams, 2015). In a similar fashion, gamification has made significant strides in education, thanks to the digital age and the inherent benefits of games (Hamari, 2017; Maican, Lixandroiu, & Constantin, 2016; Mekler, Brühlmann, Opwis & Tuch, 2013).

A gamified system, according to the model by Werbach and Hunter (2012), is made up of dynamics, mechanics, and components. Dynamics are the contexts in which the gamification occurs, mechanics are the activities within the dynamics, and the components are the objects used for the mechanics. Researchers have indicated that gamified systems in education must have three dimensions: cognitive, social, and affective (Domínguez et al., 2013; Nisbet & William, 2009). Thus, an affective dynamic based on challenge mechanics and using appealing components such as badges, points, or trophies could increase motivation and foster learning (Rincón-Flores, Ramírez-Montoya, & Mena, 2016b).

In this sense, challenge-based learning (Berland et al., 2013) can complement gamification and vice versa, converging in what has been called challenge-based gamification mechanics, since gamification could encourage students' commitment (Admiraal, Huizenga, Akkerman, & Dam, 2011; Hamari et al., 2016) and challenge-based learning could motivate their creativity by setting the innovation level.

With that in mind, the following research questions were posed:

(1) What is the completion rate based on the socio-demographic characteristics of the sample?
(2) What variables (e.g., *gender*, *age*, *educational level*) are related to the completion of the gamification challenge?
(3) To what extent does completing the gamified challenge predict student course success (final exam score)?

## Methods and procedures

This study focused on analysing a challenge-based gamification activity presented in an xMOOC about energy. The design of the gamified activity was based on Werbach and Hunter's model (2015), which stresses the emotional and social dimensions. The design of the challenging task can be considered as the mechanic component, whereas the awards (prize cups) and leader boards were the components. Participants

experienced a range of emotions when conducting the task, especially when they received immediate social feedback as the results were shown on a leader board.

**The MOOC course**

The MOOC presented in this study was part of a project titled "Innovación abierta, interdisciplinaria y colaborativa para formar en sustentabilidad energética a través de MOOCs" (Open, cross-cultural, and collaborative innovation towards energy sustainability through MOOCs) within the Bi-National Laboratory on Smart Sustainable Energy Management and Technology Training (http://energialab.tec.mx). This project consisted of the development of 12 xMOOCs, on topics covering energy reform and its sustainability; for example, "La reforma energética y sus oportunidades" (Mexico's energy reform and its opportunities), "Mercados de carbon" (Carbon markets), "Introducción a la energía eléctrica" (Introduction to electric energy) (http://mexicox.gob.mx/).

The Mexican National Council for Science and Technology and the Secretariat of Energy required the researchers to include innovative teaching practices, such as gamification, in the courses. This led to the sub-project's development within an interdisciplinary and collaborative framework composed of three teams of experts: teachers and researchers on energy topics, technology developers, and an educational innovation research group. The contents of the course were uploaded on to MexicoX, an online learning platform for MOOCs. Figure 1 shows the design of the teaching architecture applied in the energy MOOCs.
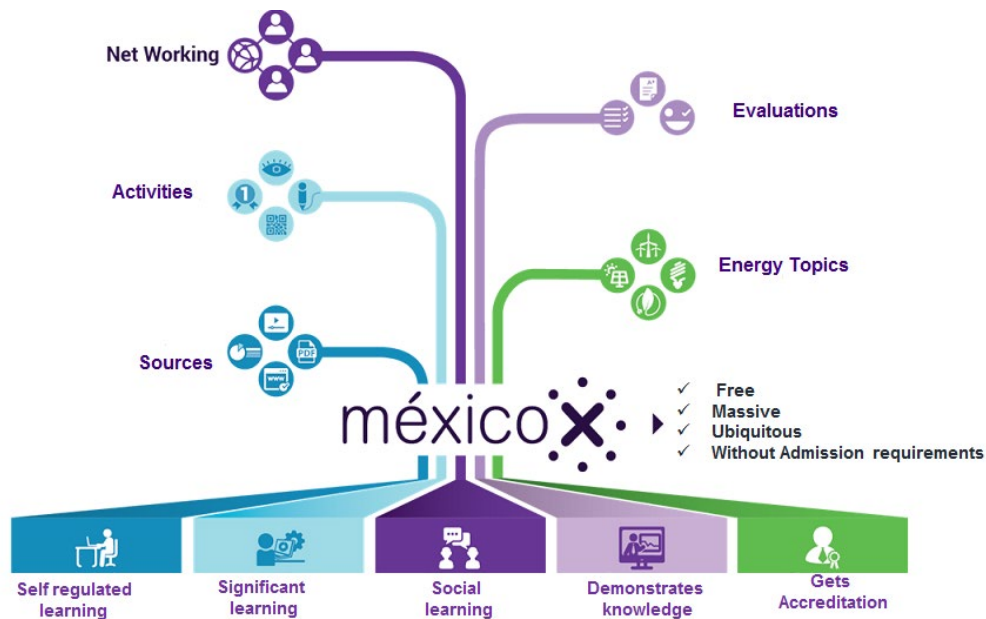


*Figure 1.* Design of the teaching architecture of the energy MOOCs using MexicoX (Valdivia Vazquez, Villegas, Farías, & Aldape, 2017, p. 22)

In the present research, we focused on the course titled "Energías convencionales, limpias y su tecnología" (Conventional and clean energies and associated technology), which took place from February 28 to April 15 of 2017. The course was designed to familiarise students with the advantages and disadvantages of energy technologies for minimising negative impacts on the environment through the selection, use, and development of most of the energy sources used in daily life. The xMOOC completion was rated on a scale of 100 points where participants needed to accumulate a minimum of 60% to obtain a certificate. Out of the 100 points, 80% corresponded to regular knowledge questions and 20% to the completion of the gamified challenge.

A series of activities involving games were designed for each course. The course type determined the design and quantity of game exercises. At the end of each course, a game challenge was included, in which the participants could win a prize in the form of a golden cup if they answered correctly on the first try, a silver cup if they answered correctly on their second try, and a bronze cup if they did it on their third try. At the

end of the challenge, the results were shown on a leader board where the participants could see their standing and that of their classmates. Figure 2 shows part of the challenge and the leader board.



*Figure 2.* Partial image of the challenge and the leader board of the course "Energías convencionales, limpias y su tecnología" (Conventional and clean energies and associated technology) (Rincón-Flores, 2018, pp. 139–140)

The chosen scenario for the gamified challenge was about sheltering in a cave because of a thunderstorm. The cave had to be lit by making a lamp out of the available resources in there: a can of ethanol, diesel, or gasoline; a glass jar; and a belt. The idea was to select the best fuel to light the cave in terms of duration of light and less pollution.

## Research design

The present study consisted of three phases. Phase 1 was a theoretical literature review on gamification used in MOOCs and its role in education. Phase 2 consisted of administering a questionnaire. In Phase 3, data was processed using MOOC analytics to obtain the results.

*Sample*
A total of 6246 participants participated in the study. Out of the total sample, 1060 students passed the xMOOC and 612 students voluntarily answered the questionnaire. The courses targeted a population over 17 years old who had finished high school, showed a marked interest in topics related to energy sustainability, and were seeking better training opportunities through online open programs. This type of training enabled participants to achieve their learning goals within a more flexible instructional environment.

*Data collection*
For the first research question, data was collected from a questionnaire on SurveyMonkey administered during the first week of the course. For research questions 2 and 3, the information provided by the analytics of the MéxicoX platform was used. Once the course ended, data was organised for the variables *gamified challenge*, *final evaluation*, *final score*, *educational level*, *gender*, and *age*. Items with incomplete socio-demographic data were discarded.

*Data analysis*
The research methodology followed a quantitative approach (Kerlinger & Lee, 2002), and the vast data was provided by the MOOC responses' worksheet. This information was related to evaluation and socio-demographic variables. All the data was processed with Minitab, R, and XLSTAT software to conduct the following analyses:

(1) Comparison of two population proportions based on independent samples and the *Z* statistic. The chi-square test is used when comparing more than 2 proportions. We performed these tests for discovering if gender, educational level, and age played a role in the completion rate of the gamified challenge. Also, we computed the 95% confidence intervals with continuity correction for proportions. This correction takes into account the skewed distribution of the estimation when proportions are not close to 50%. Confidence intervals for proportions are used for illustration in interval plots.

(2) Students' $t$ test to look for statistical differences between continuous variables sample means (Remenyi, Onofrei, & English, 2009). *P* values are used to verify the statistical significance of the evidence by which we accept or reject a hypothesis. We could be interested in finding if the means of two different random samples are the same, for example, one containing males and another containing females (called the null hypothesis). Analysis of variance (ANOVA) is used to test significant difference among means of more than two groups. We tested against differences in the final exam and final grade for gender, educational level, and age.

(3) Linear regression as a predictive technique. A continuous dependent variable is modelled as a linear combination of a set of dependent variables plus a constant and a random residual.

(4) Principal component analysis (PCA) to find the relationship between group variables. PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called *principal components* (Jolliffe, 2012). PCA, by finding the eigenvalues and the eigenvector of the correlation matrix, determines orthogonal axis of maximum variance. Variables are projected into those orthogonal axes called these *factor loadings*, whereas observations, when projected into the orthogonal axis, are called *factor scores*. Factor loadings show how variables group together. The dimension of a dataset can be reduced when factor loadings of different variables are rather close, indicating they give the same information; therefore, some variables can be removed. Also, if independent and explanatory variables of interest are grouped together in the projection, it is indicative that there might be a causality relationship between these variables. We used PCA to find the explanatory variables for the gamified challenge, final exam, and final grade. Factor scores show how observations, or students in our case, group together. Clusters of observations may eventually be observed, suggesting similitudes and differences between groups.

(5) Point biserial correlation analysis to determine if an explanatory or independent variable influences the result of a dependent variable that has only two values. For example, we can verify if doing the gamification challenge influences having a certain score level on the final exam or final grade.

## Results

### What is the completion rate based on the socio-demographic characteristics of the sample?

As noted above, 6246 students enrolled in the MOOC "Energías convencionales, limpias y su tecnología" (Conventional and clean energies and associated technology), of whom 1060 passed and obtained accreditation. This means that an overall 17% completion rate was reached (Ramírez-Montoya, García, González, Aldape, & Farías, 2017). This percentage is considered high since, on average, the completion rate for other MOOCs in online education is around 4% (Bartolomé-Pina & Steffens, 2015).

The most frequent participants' age interval was 21 to 25. As for educational level, the highest frequency belonged to undergraduate students, closely followed by high school students. Also, the fact that most of the participants were students, professionals, and teachers stands out. It is noteworthy that 10% of them were government officials and principals, which shows leaders' interest to be up to date or to learn about the topic.

Out of 1060 students who passed the *final evaluation*, 1025 students did the *gamified challenge* (97%) and 35 (3%) did not. Of the 6246 students originally enrolled, 32% were between 21 and 25 years old, whereas 35% percent of the 1060 students who passed are in this same age interval. This suggests that there was a marked interest by participants between 21 and 25 years old (students and professionals) in taking part in the *gamified challenge* and that a significant fraction did pass the course. As for *gender*, 62% of the students originally enrolled were male. This group had the highest completion rate as they comprised 68% of the students who passed the *final evaluation.*

### What variables (e.g., *gender, age, educational level*) are related to the completion of the gamified challenge?

We conducted PCA for the variables *gamified challenge* (the dependent variable of interest), *gender*, *educational level*, and *age* (explanatory variables) to identify causality relationships for *gamified challenge*.

Also, we wanted to explore the association of *final evaluation* and *final score* with our explanatory variables. Because *final evaluation* and *final score* carried similar information (they were highly correlated), we included them one at a time in PCA (Figure 3). The *final evaluation* is an important component of the *final score*. Therefore, both PCA plots are very similar, and *final score* seems to replace *final evaluation* in Figures 3a and 3b.

If there is a positive correlation, the variables will be grouped together in the biplot of the factor loadings obtained from PCA. *Gender* factor loading is small in both biplots in Figure 3, which means that it is almost perpendicular to the plane formed by F1 (component 1) and F2 (component 2). Thus, there is not a strong association between *gender* and *gamified challenge*. This is consistent with the *t* test, which shows that there is no statistically significant difference between males and females in the *gamified challenge* completion rate with a *p* value of 0.169. F1 and F2 are independent linear combinations of the original variables. In this case, F1 is the linear combination that explains as much of the data variance as possible. As noted in Figure 3, the projection of *gender* into the F1 axis is small, which means that F1 includes this variable to a lesser extent compared to the rest of the variables. F2 is the linear combination uncorrelated to F1 that accounts for as much of the remaining variability as possible. By choosing the components that explain the most data variability, PCA makes it possible to plot more than two variables in a two-dimensional plane with high accuracy.
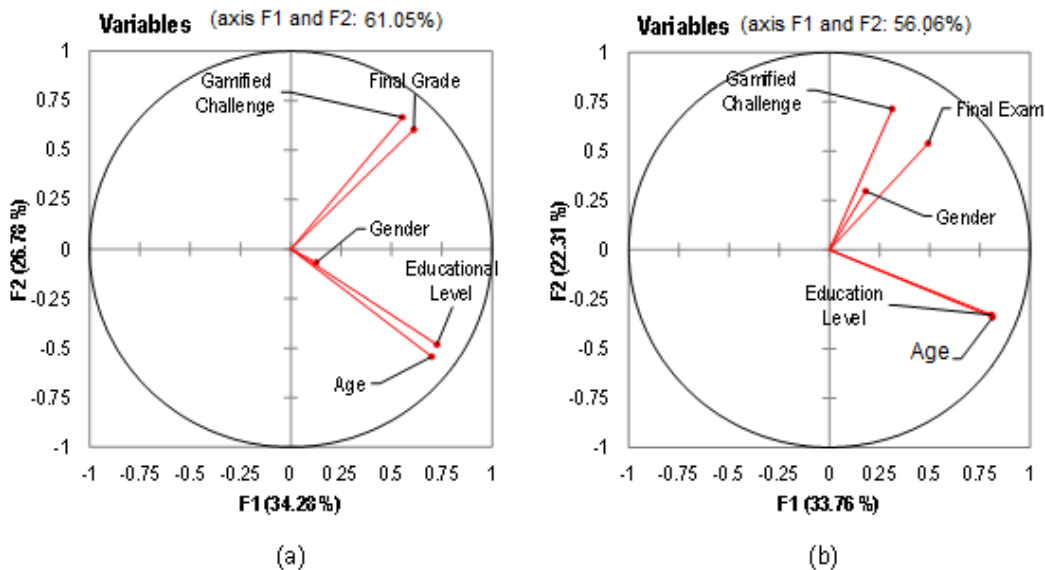


*Figure 3*. PCA correlation biplot identifying association between variables. F1 and F2 represent the two principal components.

Figure 4 shows a slight tendency for males to be more likely to do the gamified challenge than females. However, the difference is not statistically significant as the confidence intervals are overlapped.
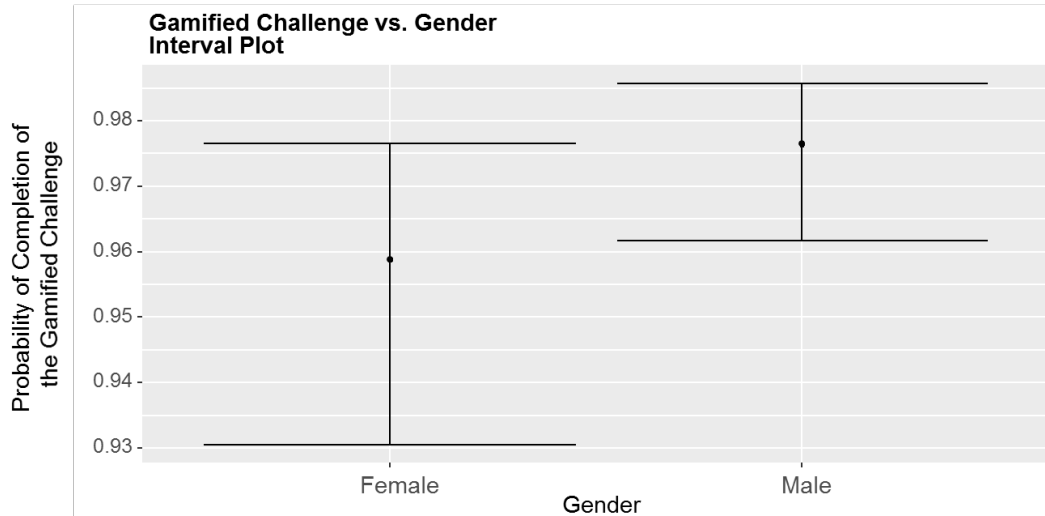
*Figure 4*. Interval plot for the proportion of participants who finished the gamified challenge by gender

When testing the educational level and the odds of completing the gamified challenge, we found that there are statistically significant differences ($p$ value = 0.0159). The means of the six types of educational levels are not statistically equal in terms of completion rate of the *gamified challenge* (Figure 5).
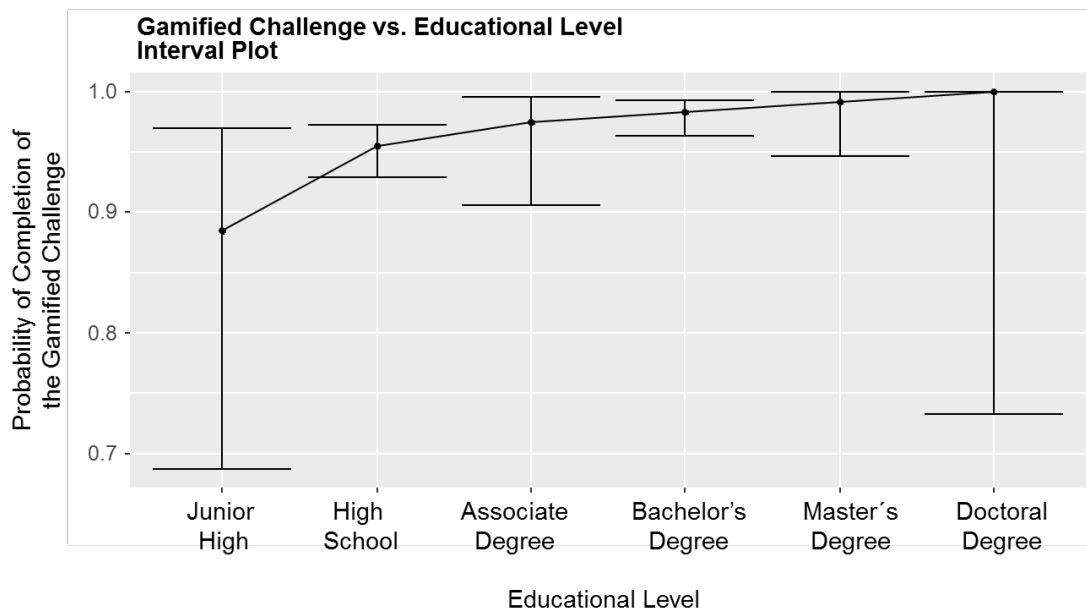


*Figure 5*. Interval plot for the proportion of participants who completed the gamified challenge by educational level

When testing against differences in the *gamified challenge* based on age, we found that there are significant statistical differences between different ages ($p$ value = 0.0114). Although results are not better as age increases, there is an age range in which the completion rate is higher, which is from 26 to 50 years (Figure 6).
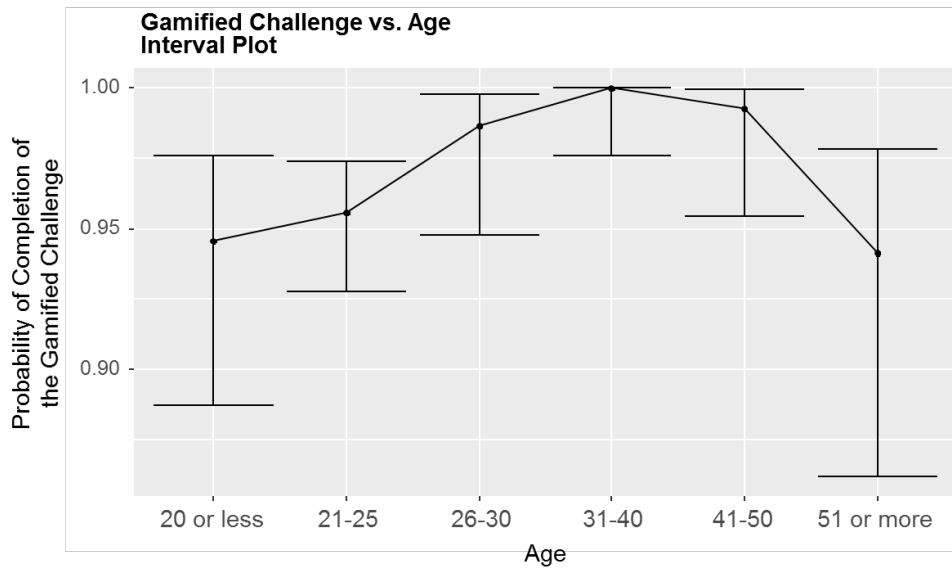
*Figure 6.* Interval plot for the proportion of participants who completed the gamified challenge by age

We identified correlations for final grade using PCA in Figure 3(a), which includes the variables *gamified challenge*, *gender*, *educational level*, *age*, and *final grade*. Figure 3(a) indicates that there is an association between *final grade* and *gamified challenge* (*p* value < 0.0001). We found that the *final score* of those who completed the *gamified challenge* (average of 0.81) was statistically different from those who did not (average of 0.45). The *t* test also showed that there were no significant differences in the *final score* between males and females (*p* value = 0.990). However, when testing against differences related to *educational level*, we found that there were statistically significant differences (*p* value = 0.001). The mean scores of the six educational levels were not statistically equal. In general terms, the three more advanced educational levels obtained a better average than the first three educational levels. When testing against differences in *final score* based on age, we found that there were significant statistical differences between different ages (*p* value = 0.034). Nevertheless, there was only a slight trend that tells us that *final score* improves as *age* increases (Figure 7).
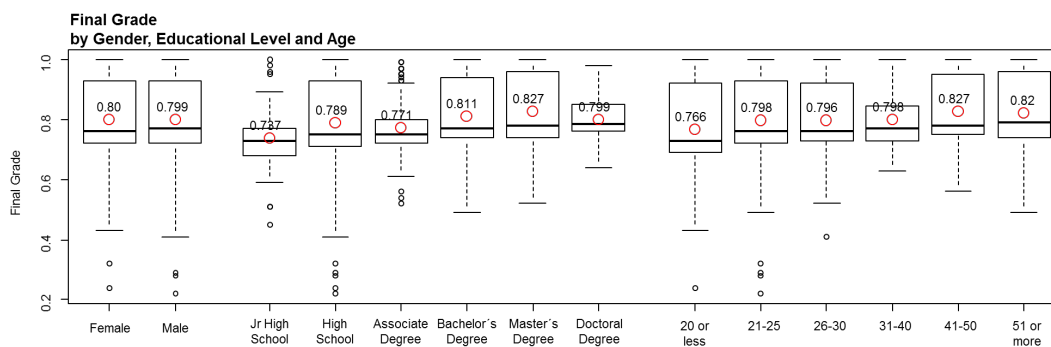


*Figure 7.* Box plots for final grade by gender, educational level, and age. The red circle represents the mean. The mean is labelled in each box.

Figure 3(b) includes the variables *gamified challenge*, *gender*, *educational level*, *age*, and *final evaluation*, and we focused on identifying associations for *final evaluation*. Figure 3b indicates that there is a causality relationship between *final evaluation* and *gamified challenge*. We found that the *final evaluation* mean score of those who did the *gamified challenge* was statistically different than those who did not (*p* value < 0.0001). The *final evaluation* mean of students who did the *gamified challenge* was 0.91, whereas it was 0.78 for those who did not.

The *t* test shows that the means between males and females on the *final evaluation* were not the same (*p* value = 0.028). Males had a mean score of 0.91, whereas females 0.90 (recall that there were no statistical

differences between males and females for *gamified challenge*). As for *final evaluation* and *education level*, with *p* value < 0.0001, the means of the different *education levels* were not the same. There was a clear trend to get a higher score on the *final evaluation* as *education level* increases.

When testing differences in final exam based on age, we found that there were significant statistical differences between different ages (*p* value = 0.015).

## To what extent does completing the gamified challenge predict student course success completion (final exam)?

Predictive models were used to explain the course students' success (final evaluation scores) based on the variables *educational level*, *gender*, *age*, and *gamified challenge*.

A multiple linear regression model was built with final exam as a dependent variable. Since our sample was comprised of 1060 students who passed the exam, this score ranged from 0.6 to 1. For simplicity, let's scale it to 60 to 100. First, we checked for multicollinearity and found that *age* and *educational level* are variables with a high correlation index (0.54). In order to avoid multicollinearity in our regression model, we excluded *educational level* and included *age* because *age* is the variable that correlates the most with the *final evaluation*. Then, we performed backward elimination in order to get a model with only significant independent variables. In our first run, *gender* was shown as a not significant variable (*p* value = 0.1190), so we excluded *gender*. We already had seen that *final score* is not statistically different for males and females and the difference in the *final evaluation* was only 1%. Finally, with our second run, our model includes two significant variables: *age* (*p* value < 0.0001) and *gamified challenge* (*p* value = 0.0006). The $R^2$ was 0.0451 for the linear fit:

$$final\ evaluation\ score = 81.86 + 5.31\ (gamified\ challenge) + 0.14\ (age)$$

This means that, on average, 5.31 more points were scored in the *final evaluation* if the student completed the *gamified challenge* and 1.4 more points are scored per every 10 more years of age.

We decided to put the variable Educational level into play by building a model that predicts an estimate of the percentage of students that will do the challenge. This is shown in Figure 8. The $R^2$ is 0.7734 for the linear fit:

$$probability\ of\ gamified\ challenge\ completion = 0.8945 + 0.0194\ (educational\ level)$$

where *educational level* is as follows: 1 = junior high school, 2 = high school, 3 = associate degree, 4 = bachelor's degree, 5 = master's degree, and 6 = doctorate degree. The linear model shows that, on average, there is an extra 1.94% of probability of completing the gamified challenge for each additional educational level (see Figure 9).
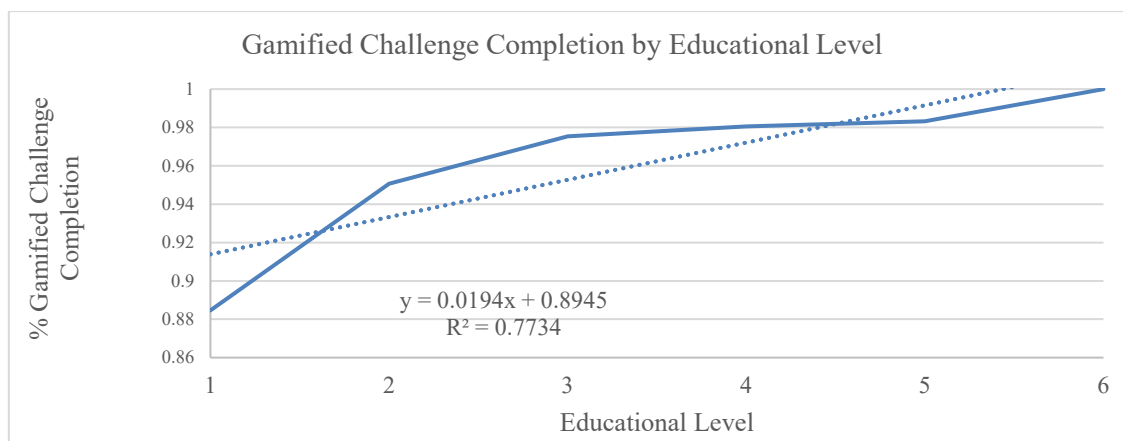


Figure 8 chart: "Gamified Challenge Completion by Educational Level" with y-axis "% Gamified Challenge Completion" (0.86 to 1), x-axis "Educational Level" (1 to 6), and equation y = 0.0194x + 0.8945, R² = 0.7734.

*Figure 8*. Linear fit for the percentage of students who completed the gamified challenge by educational level

To support the results from the prediction model, a clustering for the variables gamified challenge, age, gender, educational level, and final exam was conducted. Table 1 shows the squared cosines for PCA with the variables that are shown in Figure 3b. F1 is the principal component that explains more variability and it is mainly related to education level and age, whereas F2 is mainly related to the gamified challenge. This means that, based on the results of the Figure 3b and Table 1, older students with high education tend to have a high value of component F1 and students who undertook the gamified challenge tend to have a high value of component F2. Based on the results of the Figure 7 and Table 1, older students with high education are related with component F1 and students who undertook the gamified challenge are related with component F2.

Table 1
*Squared cosines for PCA in Figure 3b*

|  | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| Gamified challenge | 0.098 | **0.511** | 0.085 | 0.301 |
| Age | **0.662** | 0.117 | 0.005 | 0.000 |
| Gender | 0.033 | 0.089 | **0.867** | 0.008 |
| Education level | **0.653** | 0.108 | 0.008 | 0.025 |
| Final evaluation | 0.242 | 0.291 | 0.019 | **0.447** |

*Note.* F1, F2, F3, and F4 are the first four principal components in descending order by percentage of variability represented.

In Figure 9, we plotted F1 versus F2 principal component sample scores for a random sample of 250 transformed observations. As mentioned before, the horizontal axis was mainly related to education level and age, whereas the vertical axis was mainly related to gamified challenge.
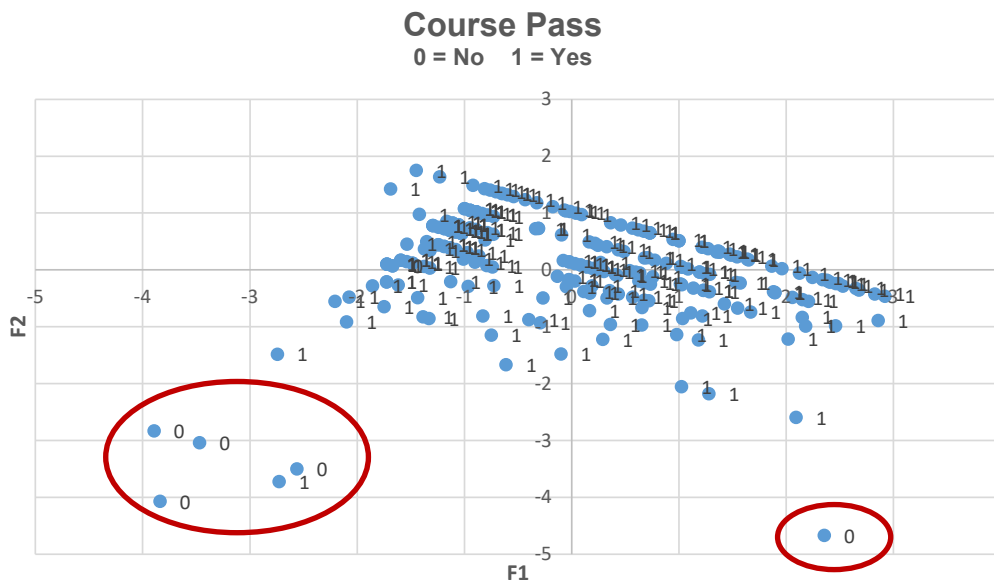


*Figure 9.* Clustering by plotting F1 *vs* F2. Red ovals indicate students with low F2. F1 and F2 represent the two principal components.

Figure 9 also shows that students with very low F2 (associated with gamified challenge) will likely not pass the course, and that many students with low value of F2 also have low value of F1 (associated with age and educational level). The big oval in the picture represents students with low values of both F1 and F2 who are most likely to fail the course. The shape of the cloud of points observed in the plot is explained by the high correlation between *educational level* and *gamified challenge* and by the binary nature of the gamified challenge. This means a student with higher level of education is more likely to do the gamified challenge.

Finally, the biserial point correlation helped to determine whether the variables *gamified challenge* and *final exam* are related to each other as well as *gamified challenge* and *final grade*. For both tests, we used

a significance level of 5% and we obtained a *p* value < 0.0001; therefore, the null hypothesis can be rejected. In other words, solving the gamified challenge is indeed related to achieving better scores in the final exam and having a better final grade.

## Discussion

The objective of this study was to determine the relationship between challenge-based gamification in an xMOOC on issues of energy sustainability and the participants' academic performance based on socio-demographic data. One of the most significant results is that, out of the 6246 enrolled students, 1060 passed the final exam; that is, the completion rate reached 17%. This high percentage is relevant, considering that xMOOC completion rates are usually low (Bartolomé-Pina & Steffens, 2015). According to Armstrong (2014) in a study carried out in Coursera, the completion rate was 4%, although Liyanagunawardena, Parslow, and Williams (2014) maintain that the global average completion rate is of around 10%. Therefore, the findings align with the objective of the Bi-National Laboratory on Smart Sustainable Energy Management and Technology Training project and turned out to be positive, especially as it is an xMOOC that teaches issues of energy sustainability.

One of the reasons that might explain this success is the genuine interest the participants showed in the course contents. The courses were especially designed to reach regular participants with average knowledge about the topic. Also, being able to get a certificate motivated some of the participants to complete the course. Almost all participants who succeeded in passing the course completed the gamified challenge. This reveals that there is an interest for this type of activity. The fact that a higher completion rate was obtained (compared to similar xMOOCs worldwide) might be partly explained by the intriguing gamification activities for the participants.

Regarding the gender, it was observed that there was no significant difference in the participation of men and women in the gamified challenge, disproving the wide-assumed belief that games are preferred by men. This contradicts the study by Lenhart et al. (2008), who found that 99% of the male participants is willing to play, while 94% of the female participants are willing to do so. It is interesting that in the MOOC of this study, men and women were equally willing to participate in a gamified activity. Meanwhile, regarding age, a *U* shape relation was observed between this variable and gamification. Higher completion rates were found in ages 26 to 50, which breaks the myth that technology is more used by the so-called millennial generation. Also, a correlation was found between the academic level and the gamified challenge. In other words, the higher the academic degree, the more inclined participants were to solve the challenge. These findings corroborate Huizinga's (2012) work, who argues that play is as old as culture itself and, therefore, it not only provides entertainment, but a way of learning.

Another interesting correlation was found between the final exam and the educational level. That is, the higher the educational level, the greater the participation in the gamified activity and the better grade in the final exam. This result confirms the importance of the cognitive aspect in gamification (Domínguez et al., 2105; Hamari et al., 2016; Nisbet & Williams, 2009) since it promotes intrinsic motivation. The majority of the participants who passed the final exam completed the gamified challenge but less than 3% of this success can be attributed to the online course methodology. This result might seem daunting; however, it should be considered that this is a traditional MOOC course in which, despite incorporating the gamification technique, the MOOC assessment still relies on traditional methods. This is not an open criticism of the xMOOC methodology, rather we raise it as a limitation – the fact that xMOOCs are characteristically massive causes technological difficulties for implementing gamification.

## Conclusion

MOOCs have been criticised because they rely on behaviouralist approaches and the completion rates are usually low in spite of the benefits of free access and academic prestige (many of them are offered by world-class institutions). Our study might be relevant because we claim that gamification can be applied as an innovative didactic strategy in xMOOCs, which are massive online learning environments that are self-managed by the participants.

Our first conclusion is that gamification may enhance motivation in xMOOC students. Although we did not find conclusive evidence that gamification was the cause of a completion rate higher than the world

average, it is worth noting that a high percentage of students who finished the activity passed the final test and finished the course. This fact suggests that gamification is a strategy that may motivate students to stay active during a large portion of the course. Besides, the topics in the xMOOC "Conventional and clean energies and associated technology" are of importance in the energy reform process in Mexico.

Secondly, this study found that both males and females participated to the same extent in the gamified activity. This is contrary to some investigations that suggest that males are more inclined to get involved in activities that include games. The pedagogical design of the gamification may have played a role in this result because the gamified activity was developed in an environment of constructive competition where all participants had the same chances to win and be recognised.

The investigation revealed that people between 26 and 50 years old were the most involved in the gamified activity. Also, enthusiasm to complete the activity grows as academic level increases. Overall, we can say that gamification is an innovative didactic strategy that helps to improve the pedagogical architecture of the xMOOCs and that stimulates the engagement of all participants regardless of age, gender, and educational level.

However, we need to acknowledge the technological limitations of the platform that hosted the xMOOC. Although the course included a gamified challenge that covered most of the course topics, the rest of the course was solely multiple-choice assessments due to the fact that this type of MOOC is characterised for being self-managed and we needed to guarantee its massiveness. Thus, we could not implement a more sophisticated gamification design based on constructivist approaches. Therefore, although technical limitations of including gamified challenges in xMOOC courses exist, it makes us consider that educational programs must tackle those difficulties and grant funding to guarantee more quality-based ways of teaching.

For future research, it would be worthwhile studying the extent to which gamification contributes to the improvement of completion rates as well as to canvassing participants' opinions on using gamification. Although this study's xMOOC on energy had a completion rate of 17%, there is no conclusive evidence that such a rate was due to gamification. On the other hand, it is suggested that the technological platform used could provide more information about the performance of the challenge in order to establish more relationships between the variables. Finally, as a next step, it would be desirable to run the same research using several xMOOCs on energy subjects with the idea of developing more comprehensive comparative analysis including multiple variables.

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