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An Analysis of the Use of Badges in an Educational Experiment

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***Abstract*—The use of badges in educational contexts its starting to gain popularity. However many studies do not offer an extensive analysis of the results regarding the use of badges after the educational experiment is finished. In this work we offer an evaluation of the results of three courses (physics, chemistry and mathematics) that we have conducted using Khan Academy with a wide badge system and 291 different students. We analyze these results regarding the distribution of badges per student, analyzing also the different badge types and which of them were delivered more often. We also explore the influence of factors such as the difficulty of problems or video length in the amount of badges triggered by exercises and videos respectively. We compare the results among the three courses trying to find possible explanations to these differences. We also put the lessons learned into context and give recommendations so that our findings can be used by instructional designers and other researchers.**

***Keywords*—badges; analytics; distance learning; Khan Academy**

I. Introduction

Gamification has become one of the main techniques that are used on educational contexts with the main idea of improving the motivation and engagement of students. The provision of badges is commonly found in gamified ecosystems where users can receive a badge after completing certain actions and badges can be regarded as a visual representation of skill or achievement [1]. Currently, there are also some open frameworks such as Mozilla Open Badges, which provide a shared infrastructure that can be used by anyone [2]. These digital badges are increasingly being used to encourage desired behaviors in many contexts, such as social networks, games and also education [3]. The use of badges in education is related to the reinforcement of achievement goal theory, since the research suggests a positive relationship between mastery learning and academic performance [4]. The main objective of gamification and the use of badges is to increase the engagement of students with the learning process, and that can be measured by different metrics such as time spent on site or frequency of visit [5]. Additionally, generally speaking students often regard the use of badges as a favorable addition to educational environments, even when they do not make a big use of them [6]

Several studies have found that badges can be used to influence student behavior on a site, e.g. to increment user activity, ask and respond more questions or other encouraged behaviors [7], [8]. We can find examples of educational studies in the literature performing a comparison between courses using gamification and others without it. For example a research using the TRAKLA2 online learning environment with 291 students randomly assigned to treatment and control groups, revealed that some badges had a significant effect on changing the behavior of students [9]. Another study found that gamified environment were able to increment social activity obtaining an increment of 511% of replies to posts and 845% more threads [10]. Nevertheless, more work is needed in this direction to learn more about the behavior of students with badges, e.g. to infer if students are intentionally earning badges or only as part of the learning process [11]. Additionally, though gamification can lead to better learning it can also have negative side effects, thus the gamified experience need to be carefully tailored [12]. This is due to the fact that badges are extrinsic rewards and can have a substantial undermining effect on the intrinsic motivation of the student [13], thus it is important to use frameworks and that the instructional design is adequate for each educational experience [14].

In this research we explore the use of badges of three pregraduate courses on physics, chemistry and mathematics in engineering education with 291 different students using our own instance of the Khan Academy platform. To obtain the different data from students we use ALAS-KA platform for the Khan Academy, which was developed as previous work [15]. The types of badges analyzed within these experiments sum more than 50 in each course and are divided in those related to exercises, videos, social interaction and course activity.

More specifically, the following research questions are stated:

1) How are the badges distributed among students? We explore the distribution of badges earned by each student analyzing total amount of badges and also the different badge types.
2) Which badge types are delivered more often? We explore how the badge type and its category might have affected the amount of badges delivered.
3) Which exercises and videos triggered more badges? We analyze which factors have an effect on this matter, for example the difficulty of exercises or the duration of videos, and also the location of these items within the course structure.

4) Are there differences among different courses? We compare the results of each one of these items for each course, trying to find possible reasons on why the results might differ from one course to another.

We try to put all these lessons into a common context that can be useful for other researchers and instructors using virtual learning environments with badges. The rest of the paper is organized as follows. First we review the badge system in our experiments using Khan Academy in Section II, then we describe the badge analysis of the case study in Section III; this analysis includes a description of the experiment (Subsection III-A), analysis of the distribution of badges (Subsection III-B), analysis of the badge types (Subsection III-C), and influence of factors in the amount of badges triggered (Subsection III-D). We finalize with some conclusions related to our findings in Section IV.

II. Badge System in Khan Academy

Khan Academy[1] is an open educational web platform which caused a big impact when it emerged because it started to redefine the rules of education [16]. The Khan Academy platform incorporates several features for gamification and learning analytics. The Khan Academy includes an *energy points* system. These points can be acquired by carrying out activities related to the learning process, such as solving exercises or watching videos. There are some other activities that can be considered as gamification components such as the possibility of establishing learning goals which are composed of exercises and videos; these goals can be seen as an analogy of achieving certain stages in games and receiving an award when the objectives are fulfilled. These elements are often regarded as part of the self-regulated learning activities that students can perform while interacting with the learning environment [17]. Finally, a strong badge system is implemented which is described in detail now.

Khan Academy implements a very complete badge system where students can receive badges as an award for their interaction in the platform. The Khan Academy system grants badges at real time whenever the conditions for that badge are fulfilled. The conditions are usually related to actions that are good for the learning process. The user can access detailed information of each badge and the conditions to get it. Students receive a notification whenever they earn a badge. Khan Academy divides the different badges into six different categories, some of these badges are very easy to acquire while others are incredibly difficult and would require a lot of effort. The first five categories are called *Meteorite*, *Moon*, *Earth*, *Sun* and *Black Hole* badges, which go respectively from easiest to the hardest badges. The conditions required to acquire these badges are very diverse, some of them are related to solving a certain amount of exercises or watching a specific time of videos. Others requirement can be associated to social interactions (such as writing or voting a comment) or earning a certain quantity of points. However, Khan Academy also has some other badges with more complex conditions such as "*Answer a problem correctly after having some trouble with many problems*" or very difficult to achieve such as "*Post 100 answers that earn 3+ votes*".

[1]https://khanacademy.org

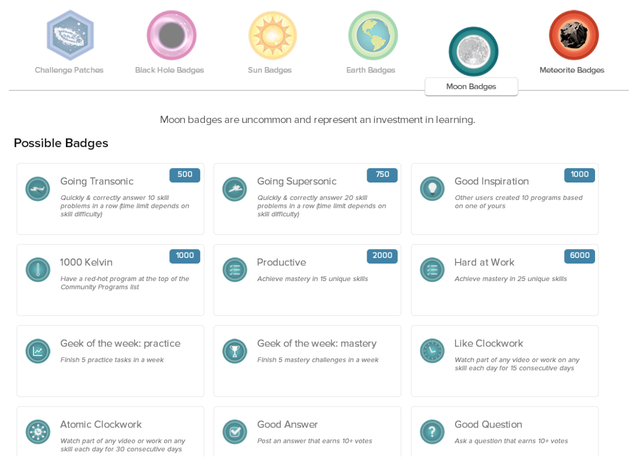


Fig. 1. Badge interface of achievements in the official Khan Academy server.

Some badges can only be earned by students once while others can be earned several times by the same student, and we denominate those as *repetitive* badges. For example the badge *Nice Streak* which reads "Correctly answer 20 problems in a row in a single skill" can be earned many times, on the contrary the badge *Making Progress* which reads "*Achieve mastery in 7 unique skills*" can be earned only one time. In addition, the sixth badge category named as *Challenge Patches* englobes challenges where students need to finish all the exercises of a complete field of knowledge. Figure 1 shows the badge classification and some examples of the badges that can be achieved of the official instance of Khan Academy.

Table I shows all badge types split in 4 categories which we have utilized for the purpose of this research. Each category contains the different types of badges that can be acquired and next a description of the requisites for each type of badge is presented. Finally, the last column has the number of different badges of the same type that can be earned of the same type of badge. As an example the *Streak* type of badge have 5 different levels which are denominated as *Nice*, *Great*, *Awesome*, *Ridiculous* and *Ludicrous Streak badge* that are triggered when the student correctly solves 20, 40, 60, 80 and 100 exercises in a row respectively. The quantity of *Topic* and *Challenge* badges is different for each course as we explain this later in Subsection III-A. Therefore, there is a base amount of common badges of 43 in all courses which is the sum of Table I and a different amount of *Topic* and *Challenge* badges for each course.

III. Badge Analysis of a Case Study

A. Description of the Experiment

The experiment is framed in the contexts of 0-courses that freshmen students have to take before starting their first year

TABLE I
CLASSIFICATION OF THE DIFFERENT BADGES IN OUR KHAN ACADEMY IN FOUR DIFFERENT CATEGORIES.

Badge category	Type of badge	Requisites	Number of different badges
Exercise	Streak	To solve several exercise correctly in a row of the same skill.	5
	Timed Problem	To solve a certain number of correct problems within a specific amount of time	5
	Exercise Completion	To complete a specific number of exercises	4
	Recovery Problem	To get exercise problems correct after having some problems solving exercises	2
	Unfinished Exercise	These badges are awarded when the user does not acquire a,proficient level but he is answering many exercises correctly	3
	Topic	These badges are awarded when achieving a proficiency level in a,subset of exercises	Different for each course
	Challenge	These badges are awarded when achieving a proficiency level in a set of exercises which are related to the same topic of knowledge	
Video	Topic Time	To watch a specific amount of videos in the same topic	4
	Video Time	To spend a certain amount of time watching videos	1
Social	Feedback	To receive up votes in your questions or answers	6
	Discussion	To flag or vote the questions and answers of other peers	4
	Profile	To customize your personal profile	1
General	Points	To earn a certain amount of points	2
	Power Time	To watch an specific amount of video and completing a certain amount of exercise problems within a set amount of time	3
	Consecutive Activity	To consecutively perform an activity on the site for a set of days in a row	3

of an engineering degree at Universidad Carlos III de Madrid. These courses have an online period of time in August where students review the concepts by themselves. Next, students take the face-to-face lessons which take place in September. This methodology in which students should prepare the lessons at home before receiving the actual lecturing class sessions where they will be able to solve their questions is known as "flipping the classroom". This methodology was applied for the first time as a pilot initiative in August 2012 for a physics course and repeated again in August 2013 and 2014 for physics, mathematics and chemistry courses due to the success of the pilot experience. The data analysis that is presented here belongs to the physics, mathematics and chemistry courses of August 2013. The courses are composed by a series of exercises and videos which have been developed by the instructors of each course. A total number of 30 exercises and 25 videos in mathematics, 30 exercises and 30 videos in physics, and 49 exercises and 22 videos in chemistry. Chemistry is the course with more exercises and less videos, while mathematics and physics are more similar. This is important as many of the badges are related to solve exercises correctly or to watch videos.

1) Participants: Students who participate in these experiences are freshmen who have enrolled to an engineering degree. Most of them have an age comprised from 17 to 19 years. The number of students is different for each course, since they might have different requisites depending on the engineering degree that they have enrolled. The number of students whose data has been analyzed in this study is 167 for the physics course, 73 in chemistry and 243 in mathematics, which make a total number of 483 different data samples. Although the number of enrolled students is higher, we have taken into account those who logged into the Khan Academy platform at least once. It is also noteworthy that as some students had to enroll in more than one course depending on their engineering degree, thus the number of different students for this study is 291.

2) Customization of the Badge System: For the purpose of this experiment, different features of the badge system were customized. First, we redefined the name of the types of badges using the names of different touristic emplacements of Madrid, so that students can be more contextualized. One of the six categories was removed as these badges were impossible to obtain in our specific context. The new type names read like *Medallas Sabatini*, *Atocha*, *Neptuno*, *La Cibeles* and *Puerta de Alcala*. In addition, new images to represent the badge types were created and incorporated to the platform as can be seen in figure 2.

Another customization was related to removing all the *Topic* and *Challenge* badges that Khan Academy has by default. New badges were added for each one of the different courses based on the new exercises provided by the team of teachers. This is necessary due to the fact that all the exercises of this experience were developed from scratch and all the exercises that Khan Academy incorporates by default were removed. In this direction, figure 2 shows the *Challenge* badges which were configured for the chemistry course. Similarly, *Topic* badges were also configured to be adapted to the existing exercises of each course and some examples can be seen in figure 3. A total amount of 7, 12 and 16 *Topic* badges and 3, 6 and 6 *Challenge* badges were added for mathematics, physics and chemistry respectively. Considering the common base of 43 badges explained in Section II, the total amount of badges considered for this research is 53, 61 and 65 badges for mathematics, physics and chemistry respectively.

B. Distribution of Badges among Students

This subsection presents an analysis of the use of badges by the students of this real experience. It is noteworthy that when presenting descriptive data such as the mean value of badges per user we use all the data samples (483 data samples), but when we perform statistical analysis such as correlation, we will use only different students (291 data samples) as independent cases in the samples are required for some statistical tests. The data sample of different students is obtained by randomly assigning those students who have

Fig. 2. Customized images and badge types for the experience. Customized *Challenge* badges for the chemistry course

Fig. 3. Configuration of new *Topic* badges for the chemistry course.

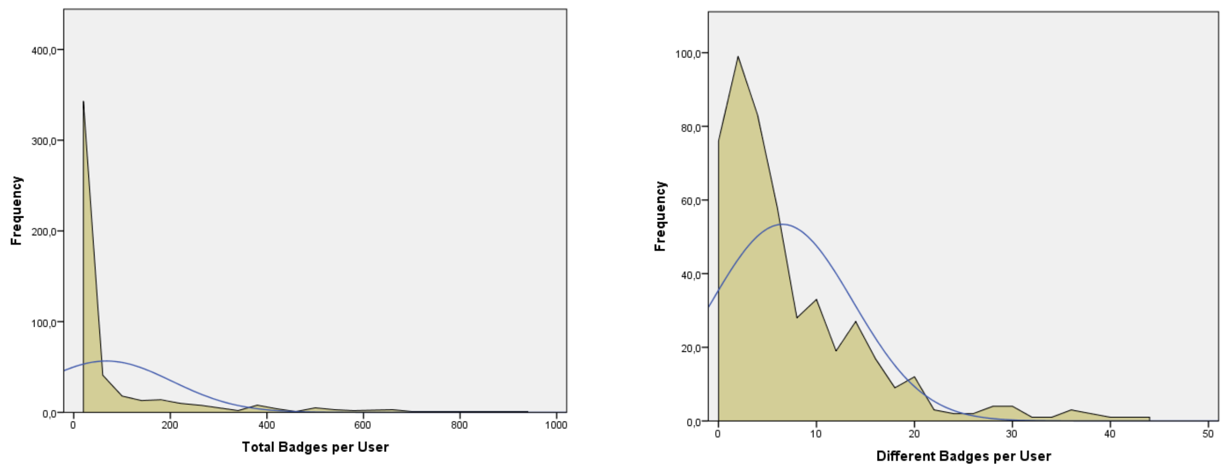
participated in more than one course to one of the courses only. The data sample of different students is composed by 164 mathematics students, 88 physics students and 39 chemistry students.

Next we present a general analysis of the achievement of badges by students of the three courses. As some badges are quite straightforward to acquire with the interaction with the platform, then most students have obtained some of them (even if they did not have the intention to get them). Nevertheless, there are others that are very hard to earn. The total number of badges delivered is 1153, 1609 and 4773 for the chemistry, physics and mathematics courses respectively. Taking into account the number of students in each course, the number of badges per student is 15.8, 9.6 and 19.64 respectively. There exists a notorious difference between physics (9.6 badges per user) and mathematics (19.64 badges per user) that almost doubles the physics number. A One-Way ANOVA was used to check whether these differences are statistically significant. The data samples are independent as each of them belongs to a different course and different users; both Kolmorov-Smirnov and Shapiro-Wilk let assume that the sample come from a distribution which is normally distributed. Finally the Levene test let assume the homogeneity of variances between groups. As the assumptions are met, the ANOVA test (F=7.9, p=0.000) demonstrates that the differences between the amount of badges per student in each course are statistically significant. These results might be associated with the fact that the progress in mathematics and chemistry courses was higher than the one in physics, and earning badges is strongly associated with the time invested by students. But there could be different causes, such as interest of students, difficulty of the topic, etc.

We analyze now how the badges are distributed among students. Figure 4a shows a histogram chart of the total amount of badges earned by each user taking into account all the courses. The y-axis represents the frequency of each case and the x-axis the amount of badges earned by the user. Additionally the blue line represents the normal curve that fits the data. This graph describes the distribution of badges earned by each user and can be used to see where most of the population is concentrated. For example, we can see an important peak in 0 and 1 badges which are those students who interacted very little with the platform. In addition, it is interesting to see how there are many students in the interval from 100 to 1000 which has achieved a big amount of badges.

Analogously Figure 4b represents a histogram of the quantity of different badge types earned by each user considering all courses. This time both axes have a linear scale. The vast majority of the population is concentrated in the interval from 1 to 10 different badges. There are important differences with Figure 4a since the previous analysis took into account all those badges that can be earned repeatedly and this plot considers each badge type once. This distribution has a more abrupt descendant curve that the other one, because most users earned few different badge types.

We can make deeper analysis by establishing intervals and comparing courses. Figure 5 shows a percentage cumulative bar chart of the distribution of the amount of badges earned by each user in five intervals which are $[< 5]$, $[\geq 5 \ \& < 20]$, $[\geq 20 \ \& <35]$, $[\geq 35 \ \& < 50]$ and $[\geq 50]$ badges earned by the user. We have also split the data by course so we can compare them. The comparison between chemistry, physics and mathematics shows that the distributions of badges earned by each user are very alike in the three courses. The most populated intervals are users who earn few badges ($[< 5]$ and $[>= 5 \ \& < 20]$) and users who earn a lot of badges ($[\geq 50]$). Here we can identify that the most common situation is to either earn a lot of badges or just few of them. Analogously, Figure 6 shows another percentage cumulative bar chart but this time it represents the distribution of different badge types earned by each user. The intervals are the same and we can see important differences between the distribution of Figures 5 and 6. A percentage of 53.4% of all the students means that more than half of the students have received less than 5 different badge types and a 41.0% of the students received between 5 and 20 badge types. This leaves a total percentage of only 5.6% of students who earned more than 20 different badge types, which seems to be a very low number, taking into account that all courses had more than 50 different badge types. These huge differences are probably due to the fact that some badges can be received repeatedly and some users might be intentionally increasing their badge count by acquiring these badges. Finally, we have not detected big differences between the distributions of the three courses as seen in Figures 5 and 6.



(a) Case I: Taking into account the total sum of badges

(b) Case II: Taking into account each type of badge only once

Fig. 4. Histogram of the quantity of badges earned by each user in all courses.

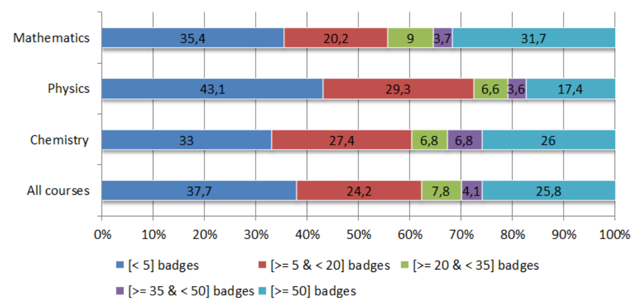


Fig. 5. Percentage cumulative bar chart of the distribution of all earned badges by each student

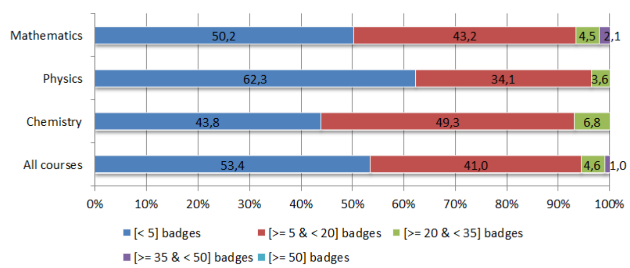


Fig. 6. Percentage cumulative bar chart of the distribution of different types of badges earned by each student

C. Analysis of the Badge Types

We explore how the badge type might have influenced in the amount of badges delivered in the different courses. Table II shows the position and count of the ten most awarded badges for each of the courses. The count is expressed in badges per user in order to normalize the value according to the size of the population of each course, this way is easier to establish a comparison among the courses. The badges included in Table II are the following. *Nice* and *Great Play List Time* belong to *Topic Time* type of badge, *Act One Scene One* to *Video Time* type, *Ten Thousandaire* to the *Points* type and *Getting Started* and *Making Progress* to the *Exercise Completion* type. These badges have different requirements that can be consulted in Table I. An interesting detail of these results is that the order of the badge types for both physics and chemistry is exactly the same except for the positions 9^{th} and 10^{th} which are exchanged. Anyhow we can see that the ranking of badges of the three courses is very similar, most of these badges have easy requirements or can be awarded many times, thus it makes sense that students have received these badges the most. None of the *Topic* or *Challenge* badges are in the top positions due to that the difficulty os these badges is higher and can be received only once. In addition, there are not social badges in top positions, which can be related to the low social participation of students using the Khan Academy platform in this experiment. We should take into account that students' main communication tool was using the forums of Moodle instead of the Khan Academy platform.

Additionally Figure 7 represents a boxplot visualization of the percentage of badges acquired by the students split by course and by the different badge categories as described in Table I. The white dashed line represents the sample mean. Students beyond the end of the whiskers are considered

TABLE II
POSITION AND COUNT OF THE TEN MOST AWARDED BADGES COMPARING AMONG COURSES

Badge type	Badge ranking position		
	Math	Physics	Chemistry
Nice Play List Time	2^{nd}: 3.3	1^{st}: 3.2	1^{st}: 3
Nice Streak	3^{rd}: 3.1	2^{st}: 1.8	2^{nd}: 3
Nice Timed Problem	1^{st}: 3.3	3^{rd}: 1.3	3^{rd}: 1.9
Great Streak	4^{th}: 2	4^{th}: 0.92	4^{th}: 1.5
Act One Scene One	6^{th}: 0.8	5^{th}: 0.5	5^{th}: 0.8
Ten Thousandaire	8^{th}: 0.53	6^{th}: 83	6^{th}: 0.6
Great Timed Problem	5^{th}: 1.2	7^{th}: 0.4	7^{th}: 0.6
Getting Started	10^{th}: 0.47	8^{th}: 0.3	8^{th}: 0.5
Great Play List Time	7^{th}: 0.7	10^{th}: 0.2	9^{th}: 0.1
Making Progress	12^{th}: 0.3	9^{th}: 0.2	10^{th}: 0.3

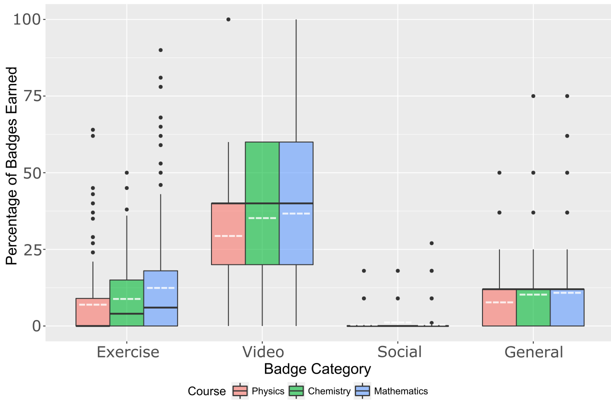


Fig. 7. Boxplot visualization representing the percentage of badges earned by each student divided by badge category (*x*-axis) and course (fill color).

outliers and plotted as black dots. The first glance can confirm that even after splitting by badge category, mathematics was still the most active course in badges and physics the least one, as we saw in previous subsection. This visualization confirms that not many social badges were delivered, as social activity within the platform was not very widespread. Video badges have the highest median since there were only 5 different video badges, and some of them were easy to acquire. We can find some interesting outliers such as the physics student who achieved all video badges, or some students within the mathematics course that achieved more than 75% of all the exercise badges.

D. Influence of Exercise and Video Factors

Some badges are triggered when solving exercises or when watching videos, thus it is interesting to analyze which exercises and videos trigger the biggest amount of badges. The causes can be very diverse, for example an easy exercise can be used to obtain many correct exercises in a row or a difficult topic might trigger more video badges because students need to watch the video more than once. Table III shows for each one of the courses the two exercises and videos which triggered more badges. There are some important differences between those exercises and videos which triggered the biggest amount of badges and those which triggered the least; as an example for the math course, the exercise which triggered more badges is the *Biquadratic equation* exercise with a 301 badge count whilst *Basic operations with complex numbers triggered* only 31 badges. These differences are also applicable for the other courses and in videos as well. We have analyzed the possible reasons for these results, we take into account the following factors:

- Location: This is a variable which represents the order and location of the exercise or video within the course structure. Each course has a recommended path to follow and we hypothesize that contents placed at the beginning of the course are more likely to trigger a bigger amount of badges.
- Percentage correct: This numeric variable represents the correctness ratio of each type of problem and we use it to operationalize the difficulty of an exercise, hypothesizing that easier exercises are used to obtain more badges.
- Duration: This variable represents the time length of a video.

We found a positive and moderate correlation between the badge count and percentage correct for exercises $(0.45, p < 0.00)$ which seems to indicate that easier exercises trigger more badges, which makes sense as it is more accessible for students to solve those exercises correctly. Also we found a correlation between badge count and duration in the case of videos $(0.5, p < 0.00)$ which might mean that longer videos trigger more badges, and the rationale behind this result can be that students need to spend more time on the video, thus it is more probable that they earn some of the *Video Time* badges. These correlations are presented for all the exercises and videos from the three courses, but are also maintained when performed within the data from each course separately.

We make a more in-depth and graphical analysis for the case of badges triggered by exercises in Figure 8. We explore how the normalized badge count is affected by percentage correct and location variables, separating also by course. We express the badge count as normalized z-scores ($z = \frac{x-\mu}{\sigma}$), otherwise the difference between the number of students in each course would complicate comparing the amount of badges triggered. The plot in the top of the figure shows a visualization where each point is characterized in the *y*-axis by the normalized badge count and in the *x*-axis by the percentage correct of that type of exercise. Additionally we draw the regression line with the standard error (shadow) which shows in all courses a positive tendency suggesting that the higher is the correct percentage ratio of the exercise the more badges were triggered by the exercise. The bottom visualization shows a line plot representing on the *x*-axis the location of the exercise within the course structure being the left side the first exercise and the right side the last one. It appears that as expected those exercises located at the beginning of the course triggered more badges than those at the end, except for a peak in the middle-end of the chemistry course. The exercises that caused the peak in the chemistry course are 'Le Chatelier Principle' and 'Lewis Structure'. These exercises have been solved correctly many more times (around twice) than others located nearby within the course structure, consequently triggering more badges. Although we cannot establish the causes with certainty, we can hypothesize that maybe the difficulty was easier and students used these exercises to earn more badges or that the topic was appealing for students increasing the amount of activity. These results are aligned with the negative and significant correlation between the location of the exercise and the badge count $(-0.46, p < 0.00)$, which seems to indicate that as the location of the item within the course structure advances, it will trigger less badges.

TABLE III
TOP-2 OF EXERCISES AND VIDEOS WHICH TRIGGERED MORE BADGES IN EACH COURSE

	Exercise	Video
Math	Biquadratic equation Derivatives I	Functions: domains Derivatives II
Physics	Force diagram Scalar and vector magnitudes	Circular motion Newton's Laws
Chemistry	Atom and subatomic particles Quantum numbers	Electronic levels Le Chatelier's Principle

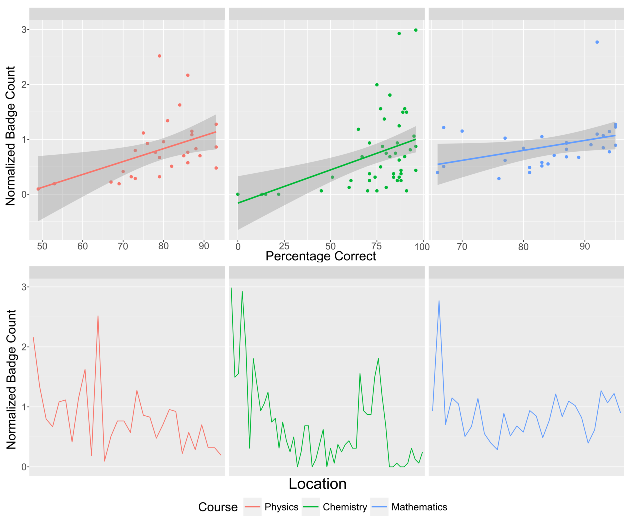


Fig. 8. Influence of factors (percentage correct and location within course structure) in amount of badges triggered by exercises

IV. CONCLUSION

In this study we have performed an evaluation of the use of badges in three courses using Khan Academy platform with 291 different students. We have tried to set these results into context as lessons learned to provide some recommendations for future learning experiences in engineering education using badges. We found some students that earned many badges, while others did not make much use of the badge system. For example we found more than 80 students who earn 100 badges or more in one course, and 15 that earn 500 badges or more. This might be an indicator of the interest of those students in badges. We might use this information to provide adapted learning and personalized recommendations for each student. However we should also keep in mind, that as badges are extrinsic motivators, we must be careful with our design. Some of these students repeatedly earned some of the badges by resolving systematically and fast easy exercises. We are concerned that this behavior might not improve learning for them, and can be indication of an external motivation. That is why we recommend instructional designers to focus on trying to boost the intrinsic motivation of students [18].

We also analyzed the type of badges that were delivered more often. We found interesting that the 10-top ranking was almost the same for the three courses, despite the fact that different students interacted in each one of them. Although some of these badges were easy to acquire through some participation, others such as *Great Timed Problem* or *Great Streak* required more effort. We believe that easy participatory badges, will not play a key role in the motivation of students, but instructors can reinforce complex exercises or concepts with skill badges, so that students can have an extra motivation to master those concepts.

We found that the amount of use of social interaction within the platform was low. One possibility would be the use and provision of additional badges for students performing social activity tasks such as voting, commenting or posting threads. This social badges could be included as part of the summative assessment activities taken into account for the grade, which would represent an additional motivation of students to use them. Additionally, it would be helpful to make more clear for students the social activities available within the platform. This same idea can be applied for encouraging other different types of activities.

We have explored the factors that might influence the amount of badges which are triggered by exercises and videos. Despite we are not able to report conclusive causes for these results, our findings suggest that easier exercises and longer videos trigger a bigger amount of badges. Therefore, we might want to facilitate the acquisition of badges for those exercises that are harder to solve. Additionally, the course order plays an important role, taking into account that the contents that are placed at the beginning of the course tend to be accessed more frequently, thus more badges were triggered. For that reason, if we expect students to be dropping out as the course advances, we should place motivational badges in the middle and later sections of the course, in order to keep students engaged through the contents.

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