Engaging to analytical chemistry through in-class TV-based contests

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ABSTRACT

Herein we describe the results of a pilot project to make more participative review sessions in small groups of two subjects of Analytical Chemistry module in a Chemistry Bachelor Degree through games based on TV-shows. Previously, the usual classes were focused in solving homework assignments, both problems and short questions so the students' preparation was restricted to known specific points of the topics and mainly passive roles. In the proposed activity students did not know the questions in advance, which obliges them to a more comprehensive study and they need to pay attention and be active throughout the classroom. This task provided an entertaining learning environment and students benefited of group study. They learned which aspects seem to be more relevant in the vast information gathered during the theory classes perceived as a succession of methods and techniques barely distinguishable. The two-step quizzes (individual and collaborative) were performed using instant polling with and without mobile-phone devices to obtain immediate results in the screen as well as feedback from the instructor or colleagues. The overall satisfaction was very high and students encourage us to continue developing these enjoyable strategies in the future with some interesting modifications.

Keywords

Undergraduate students, Analytical Chemistry, gaming, TV-show quiz, instant-polling systems, collaborative learning

Introduction

Keeping the interest and enthusiasm of students to attend classes is becoming more and more difficult due to the easiness they collect specialized information while staying at home. The instructors usually provide them slide presentations through the university on-line platform with most relevant points. This information is often considered enough to skip (some) classes. In the case they need more complete information students have access to open courses from many universities and stunning videos with clear explanations that they can revise anytime everywhere. The use of recommended books is seen as the last resort for certain especially tough topics. In addition to this, in some Higher Education Systems, attendance to classes is only compulsory to the laboratory sessions. In our university, group tutorial (review) classes are also mandatory and they are scored with a (small) percentage of the final subject mark.

Online education including entertaining video games [1] is thus a threat but also an opportunity to make the university classroom a worthy experience through innovation. The generation Z (born between 1995 and 2012) who is filling the classrooms these days has growth up immersed in digital technology both at home and at school and are highly dependent on immediate feedback and reward [2]. Presumably, the lower technologically advanced environment they encounter is the university classroom that often lacks digital or electronic whiteboards. Incorporation of technology should not be restricted to standard tools but extended to other gadgets [3] that promote an active student's participation rather than just taking notes of lectures or problem solutions, which seems to be a cumbersome activity for those who were not trained at high school level.

In an attempt to engage students to a daily study of Analytical Chemistry and help them to extract the key features of the intricate set of analytical techniques, we show here a

pilot gaming project for review classes. Gaming promotes active learning [4] and healthy competiveness enliving classroom sessions [5]. Until now, most of these classes were devoted to solve student's doubts or homework problem sets. However, passive students take benefit from other partner's questions, usually scarce because of their random study habits or for fear of asking ridiculous questions. On-line instant polling platforms, with and without the need of smartphones, disable those complaints. Most apps allow anonymity providing a non-threatening environment for students who cannot longer skip participation. They are adapted to *digital natives,* who seem to be more visual and tactile than listening learners. Besides they provide real-time answering simplifying result collection and record keeping [3,6]. Gamification is more intensively used in primary and secondary schools but it is increasingly common at university level [4,5,7-9] combined with on-line gaming apps [10-12], though less faster than expected [13]. Inspired by previous examples using TV quiz-show games, such as *Who wants to be a chemical millionaire?*[4,14], we implemented a tuned version of it in two analytical subjects. Before attendance to the revision gaming classes, students were previously trained during theory sessions in handling different response platforms and in the type of questions they can expect. The biphasic games consisted in a selection phase scored individually to then play the collaborative step scored as a group. After the session, students were asked a survey about their experiences.

The context: peculiarities of the Higher Education System in Spain

The construction of a comparable and compatible Higher Education System (HES) in Europe and beyond (now 48 countries) has led to the implementation of a student-self center learning process and a reduction of one academic year in Bachelor degrees in Spain, one of the few countries opted for 4-year degrees. HES also brought the

opportunity to adapt the student workload to a realistic content in order to correct the disagreement between the Degree duration and the average time to graduate. According to official statistics from University of Oviedo, as an example, the reformed Degree requires about 55% less theory and lab sessions [15] but the average number of years to graduate is reluctantly above 5 years (5.2 in the last recorded academic course, 2017-2018) with a poor 16.1% of students graduating without delay [16]. The number of in-class hours of theory for the Analytical Chemistry (AC) module in Spanish Universities is well above the European recommendations [17] of 100 h (between 115 and 225 h). The level of experimentation is consequently below the recommendations, an average of 41.6 vs 66%. This along with a comprehensive curriculum could explain the high workload that yields a low success rate. An additional feature of our faculty shared by one third of Chemistry degrees in Spain is the full separation of theory and practice (lab) in distinct and consecutive subjects. Theoretical learning is therefore not enriched with handling instrumentation and facing operational difficulties. Overall, it is not surprising that students' vision of AC is a mixture of undistinguishable techniques.

Quiz contests methodology

In this context, gaming was considered as a useful tool to help unravel the intricate series of techniques and emphasize the more relevant and confusing points. The previous academic year we proposed a simulated interview in pairs where one student was an analytical chemist and the other was a person with less or no knowledge of the subject (a relative, a friend, etc.) to practice oral skills in explaining different techniques and to adapt the speech to the listener level. That activity was not as welcome as this one especially because we wanted to record a video. This time, the gaming sessions were set up in a review class after a traditional one (doubts and problem sets) in two

subjects: the introductory second-year (2Y) Analytical Chemistry I and third-year (3Y) Analytical Chemistry II, which deal with analytical features, the analytical process, titration and gravimetry, UV-vis and fluorescence molecular spectroscopy, flame atomic spectroscopy and electroanalytical techniques.

The game consisted in two phases implemented in 50-min sessions with a reduced number of students (max. 10 students per session). The initial phase consisted in five simple questions that can be quickly answered by using Kahoo.it, a mobile-phone based polling app, with the purpose of selecting the group leaders. The app ranked participants on both correctness and response-speed but we graded each student only according to the former because of differences in connection speed between smartphone brands. This accounted for 50% of the session mark to discourage students to respond incorrectly to avoid taking the responsibility of being the leaders in the second phase.

The second part was the TV-based game. Second-year students used Plickers, a mobile-free polling system that requires the use of individually-assigned cards displaying a squared form with a letter at each side. Rotating the card to show the letter to correspond to the correct answer in the upper part is the only action students need to do. The instructor scans simultaneously all cards and the results are immediately displayed on the screen. Third-year students used Poll Everywhere, a mobile-based polling app that secures anonymity with a back-channel for instructors to collect this hidden information if desired. In both cases the game consisted in answering fifteen questions. All 3Y students were urged to answer the questions but only the leader decided whether or not keeping the most voted answer shown on the screen or which the final answer was in the case of a tie. Each group had three lifelines: one “take a fifty:fifty”, and two “call a friend” because the usual third lifeline “poll the audience” is the basis of the contest in this version. Team working skills were worked in pairs (and a trio) with the

2Y students to create heterogeneous subgroups in which peer discussion favors collaborative learning as well as better results in the contest. All subgroups were led by one top-ranked Kahoot student who selected their partner from the rest. All questions were different from those used previously in class for clicker training purposes and were answered by all groups/students irrespectively of their evolution in the contest, that is, after failure in order to maintain students' engagement throughout the session. Students were asked to justify their answer to know whether the option was selected by chance, possibility that cannot be ruled out in multiple-choice questions with a single correct answer and discussion was completed by the instructor. Students were finally graded based on the correct answers of each group or subgroup.

Since 3Y games were played in two different days, two sets of questions (A and B) of similar difficulty were prepared for both Kahoot and Poll Everywhere. It is important to note that students' registration in the app implies access to all questions answered so first-day participants can communicate the questions to second-day participants.

Contest's results

During the individual phase, different distributions of correct answers were obtained not only between two groups playing identical game (Fig. 1A) but also between groups playing different game (Figure 1B). Curiously, the second trial showed narrower distributions shifted to higher score, which can be ascribed to knowledge of the question difficulty in the case of 3Y students that played two days after the first group but can be only related to poorer knowledge in the case of 2Y students who played in two consecutive sessions without opportunity to share information. The absence of 0 score points to influence of chance when answering as well as the lack of 5 score among the 2Y students.

Results for Plickers-based second phase are summarized in Table 1 and for Poll Everywhere in Figure 1C and Table 2. All pairs/trio (2Y) or individuals (3Y) provided correct responses for at least 8 out of 15 questions (more than 50%) except in a single case (7 out of 15). In particular 5 questions were successfully answered by all second-year pairs but only 2 questions out of 30 from both sets achieved 100% correct answers individually showing the power of team working. This agrees with a 60% and 50% of questions successfully answered by more than 80% of 2Y and 3Y students, respectively. On the other side of the score, up to 5 out of 15 questions were failed by more than 60% of pairs (max. 80%) while only 2 by individual students (max. 64%) showing that chance is playing a role when answering individually. During the discussion following most failed questions, the majority of students recognized not having processed that content in theoretical classes. Therefore, the game offered valuable feedback not only to students but also to instructors to know where major difficulties are concentrated. Of note, the poorest result was achieved by the only 3-member group (group A) pointing out to greater difficulties to achieve consensus in a limited time period, though the fact that two of the partners attained the poorest Kahoot results should not be overlooked. Regarding the results as a group under the TV-show rules, the four 3Y students groups (G1-4) showed striking differences. G1 and G2 failed game A at questions 5 and 6, respectively, sooner than instructor's expectations achieving a poor score, while group 3 failed game B at 13th and group 4 successfully completed the contest, in line with better results obtained in the selection phase (see game B in Fig. 1B). Since the game continues after failure, we can compare the total number of failed questions as a group with the individual results shown in Figure 1C. G1 and G2 failed two additional questions so the overall mark in a regular test would have been 12/15 (Table 2). G3 and G4 did not fail additional questions obtaining a group mark of 14/15 and 15/15,

respectively. All groups excelled the test but the strict rules of the game penalized early failures at easier questions. Individually, the most abundant number of successful questions was 12 and 11 for G1 and G2, which contrasts with the early wrong answer as a team. Distribution in G3 and G4 was wider. Only in G4 there were students with 14 and 15 correct answers, which explains the success of this group. The individual average scores (Table 2) are quite similar for the two games but the contest results was strikingly different. While G1 and G2 unexpectedly performed worse as a group than individually, G3 and G4 showed the power of the group decision making. The anomalous results of the G1 and G2 might be related to the leader. The instructor's perception in class before knowing the individual answers was that G1 and G2 leaders were less self-confident and more reluctant to use the lifelines. They felt uncomfortable with the unexpected role assigned even verbalizing that they were not a good candidate. As an example, the first G1 failure was the consequence of keeping the leader's own decision when the group mostly selected the right option (6:2). In the following failed question, this group leader decided to change his/her own decision that was correct showing lack of confidence. Group leader 2 failed 5 questions individually, among the worst of this group. On the contrary G3 and G4 leaders actively promoted discussion after seeing the overall results on the screen to find arguments to decide and they used wisely some lifelines asking those colleagues they know are trustworthy. They intelligently pushed the group to higher scores than they would have obtained individually, including themselves; they asked successfully 11 and 13 questions, respectively.

Second day sessions were more active and more enjoyable for the students. Although it was not expected they talked with the leader to decide unless they have taken the corresponding lifeline. The instructor decided to allow this practice because of the

fruitful discussions among peers. At the end, they suggested to change the call lifeline by a 15 s revision of the class notes, something that will be tested next academic year.

Student's opinion

A unique and anonymous survey was sent to all 40 students taking advantage of this feature of Poll Everywhere. 55% of them answered some questions and 50% completed the poll. The overall satisfaction was high, above 7 in both subjects; 7.4±0.9 and 8.1±1.2 for second and third year students, respectively (Figure 2A). When asking about pros and cons of each app, surprising differences were found between the youngest and oldest students. While 2Y alumni showed preferences for Kahoot due to easiness of use, attractive interface and even the pressure time, 3Y alumni criticized this latter feature and the need of reading the answers in the room screen given that in the mobile app only the answer logo/color appears. Implementation of clickers in primary and secondary school has been progressive so the exposure to these tools might be higher for younger students. Most of 2Y participants (82%) reported previous experience with Kahoot in a learning context (namely at high school) which would explain the absence of anxiety. However they complained about the inability to change the answer when clicking the erroneous button from technical issues with the mobile app. In students' opinion Plickers resulted more disruptive in class. When asking to score each program results (Table 3), Poll Everywhere obtained the best scores in both classes but with higher value among the third-year students while Kahoot score was similar, suggesting more generous grading from the oldest. Plickers obtained the lowest average score, though the lowest absolute individual score was collected by Kahoot (3 in a 0-10 scale). Regarding the influence of the contest in the study habits and its results in the final exam, 76% of students recognized these activities have encouraged them to study

because the mandatory participation and grading without previous knowledge of the questions as in homework assignment-based sessions. They are confident this will be reflected in the final mark not only for the early study but also because they can revise the questions before the examination. The rest declared no influence. Most students felt well (happy or very happy) when performing the activity with only 1 students reporting nervousness (Figure 2B). Finally, all but one, recommend implementation of this type of activities in the specific subject or even in all subjects (40%).

Concluding remarks

The announcement of special activities as TV-based contests has been generally welcomed. These collaborative games are preferred to oral activities because the limited exposure to group and instructor scrutiny. Among the most favorable aspects of quiz contests students pointed out the opportunity to confront their knowledge and debating topics with peers. Students enjoy group learning processes but their approach to this task is mostly individual in spite of the variety of tools on hand that makes communication is easier than ever before. The feedback was very positive which encourage us to repeat the experience in next academic years with some small modifications following students comments as allowing them to revote using apps with this option such as Poll Everywhere or including novel lifelines. Finally, we feel this activity has served as a catalyst to promote active learning at class. It prompts them to study harder and students appreciate the benefit of it.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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TABLES

Table 1. Results of the Plickers-based contest performed by second-year students (Analytical Chemistry I). C: correct answers shown in green, W: wrong answers shown in red.

	Group	Correct answers	Failed questions	QUESTIONS														
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Session I	A	8/15	4-6, 8, 10, 12, 15	C	C	C	W	W	W	C	W	C	W	C	W	C	C	W
	B	10/15	1, 4, 8, 10, 12	W	C	C	W	C	C	C	W	C	W	C	W	C	C	C
Session II	C	12/15	1, 8, 10	W	C	C	C	C	C	C	W	C	W	C	C	C	C	C
	D	10/15	1,8, 12-14	W	C	C	C	C	C	C	W	C	C	C	W	W	W	C
	E	12/15	1, 10, 15	W	C	C	C	C	C	C	W	C	W	C	C	C	C	W

Table 2. Results of the Poll Everywhere contest performed by third-year students (Analytical Chemistry II)

	Game A		Game B	
	Group 1	Group 2	Group 3	Group 4
Questions failed	6, 10 & 14	5, 11 & 14	13	none
Contest score	6/15	5/15	13/15	15/15
Group score	12/15	12/15	14/15	15/15
Individual average score	10.6±1.4	11.8±1.1	10.5±2.0	11.6±2.8
Average score per game	11.2±1.4		11.0±2.4	

Table 3. Satisfaction score of each polling app separated in second and third year classes (scale 0-10)

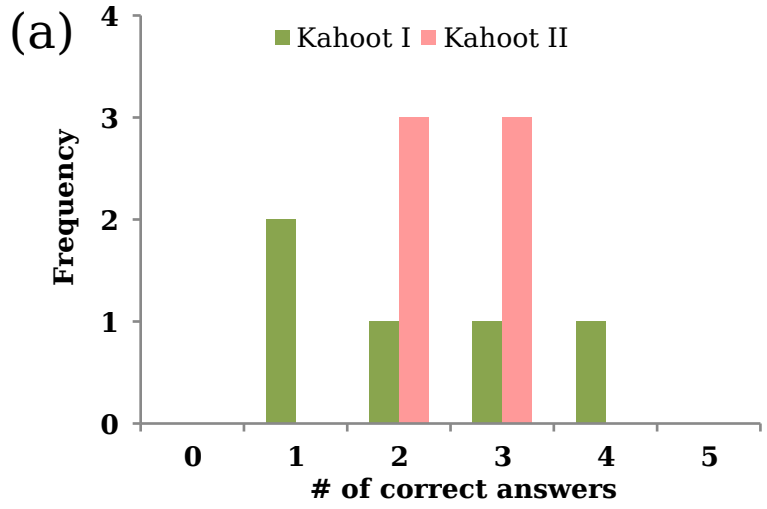
	Second year			Third year	
	Kahoot	Plickers	Poll Everywhere	Kahoot	Poll Everywhere
Average	7.3±2.3	6.2±1.4	7.8±1.4	7.8±1.5	8.6±1.1

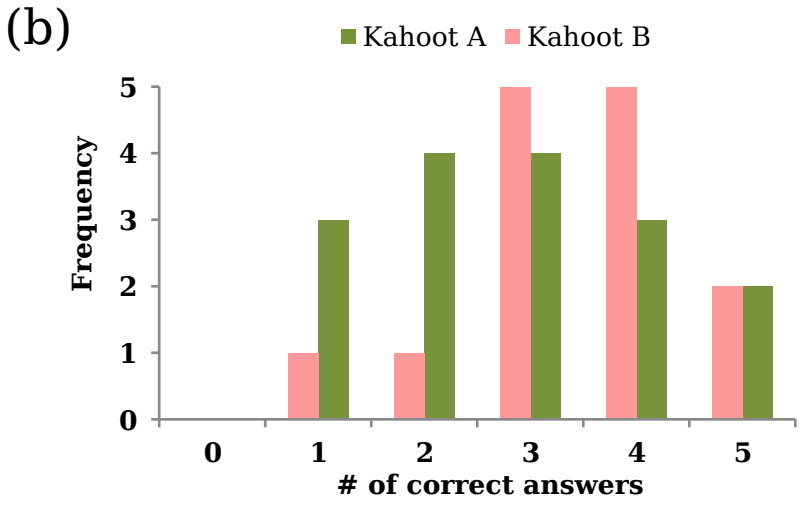
FIGURE CAPTIONS

Fig. 1 Histograms showing the number of correct answers as a function of its frequency (number of students). a. Kahoot selection phase played by 2Y students in two separate but consecutive session I (green dark color) and II (pink pale color) using the same game. b. Kahoot selection phase played by 3Y students in two different days, game A (green dark color) and B (pink pale color), respectively. c. TV-show phase using Poll Everywhere played by 3Y students in two different days; game A (green dark color) and game B (pink pale color)

Fig 2 a. Overall second year (outer circle) and third year (inner circle) students' satisfaction in a 0-10 scale. b. Overall emotional scale when performing the game.

Fig. 1


(a)
Kahoot I
Kahoot II
Frequency
0
1
2
3
4
0
1
2
3
4
5
# of correct answers


(b)
Kahoot A
Kahoot B
Frequency
0
1
2
3
4
5
0
1
2
3
4
5
# of correct answers

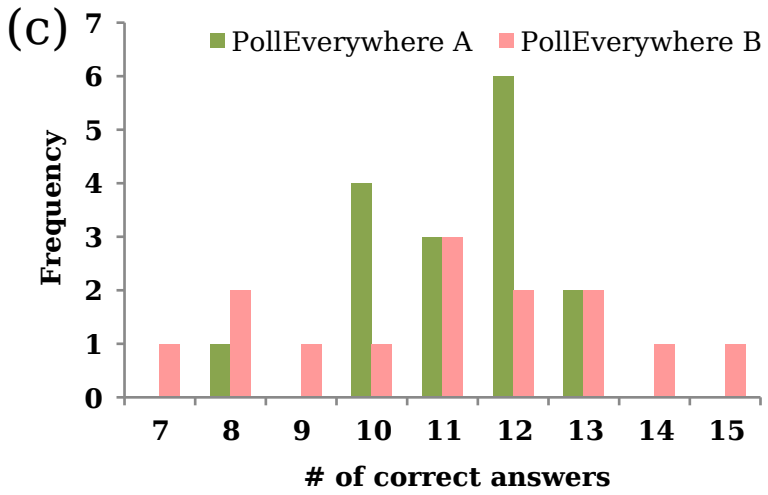
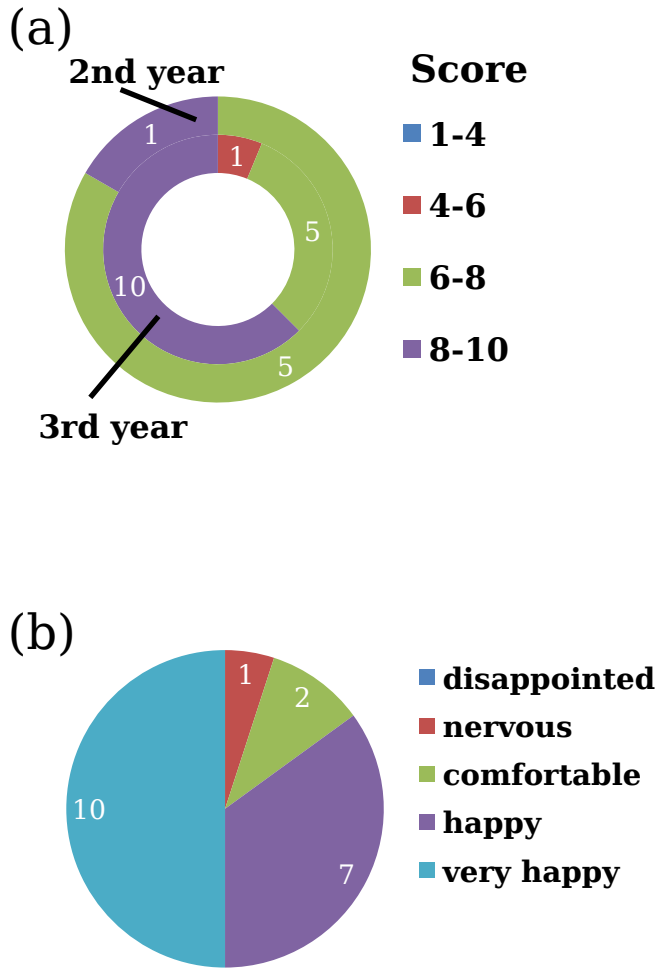

(c)
PollEverywhere A
PollEverywhere B
Frequency
0
1
2
3
4
5
6
7
7
8
9
10
11
12
13
14
15
# of correct answers

Fig. 2


(a)
2nd year
3rd year
1
1
5
10
5
Score
1-4
4-6
6-8
8-10
(b)
1
2
10
7
disappointed
nervous
comfortable
happy
very happy