Design and Evaluation of a Gamification-based Information System for Improving Student Attendance

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Abstract

Declining student attendance is a recurring concern in most educational environments, including tertiary education. Depending on the assumed cause of low attendance, different approaches have been proposed as a means of intervention for mitigating the problem. On the other hand, gamification is a relatively new approach that aims to increase engagement of participants in non-game contexts by utilizing techniques developed for and used in computer games. In this paper, we propose a novel approach that aims at intervening by applying gamification techniques for the purpose of increasing the extrinsic motivation for attendance in tertiary-level education settings. The approach is based on a cloud-based platform which features web and mobile clients. The main stakeholders are the lecturers, who can configure the environment, and the students who are the targeted participants. Unlike similar works, this approach aims at improving the student attendance at a wider scale, e.g. at the programme level rather than focusing on individual modules or classes. Additionally, it provides fine customization allowing the lecturers to opt in with custom settings. Finally, the paper describes some early results and paves the road for an extensive evaluation.
Keywords: Gamification, Behavioural change, Information System.

1. Introduction

Student attendance is a contemporary concern in modern educational settings. Low attendance has been associated with low performance [16]. To deal with this, multiple approaches have been proposed which focus primarily on increasing intrinsic motivation. For example, some works have focused on involving the students' family and their community in general [9, 22]. While there is already evidence of gamification helping to improve student engagement in learning in general [18] and student attendance in particular [6], this paper proposes a novel platform that is designed to be customizable and reusable. It mainly aims at improving student attendance at the program level.

The main contributions of this paper are: First, the presentation of a novel gamification-based approach for improving student attendance. Second, a flexible and extensible IS architecture for behavioral change using gamification. And third, the evaluation and demonstration of behavioural change in a case study that aimed to improve student attendance.

The rest of this paper is organized as follows: Section 2 presents the IS architecture, and de-

scribes its main components. Then section 3 describes in detail the evaluation process, covering the methods used and results obtained. A discussion and an overview of related work are then covered in section 4 and the paper closes with conclusions and future work in section 5.

2. Information System Architecture

Motivated by the successes of gamification, as well as the relevance and timeliness of the challenge of improving student engagement and attendance, we delved into the development and evaluation of a gamification platform. The platform involves an extensive information system, allowing the main stakeholders to set up and participate to scenarios involving gamification.

The main stakeholders are the *lecturers* and the *students*. The lecturers use so-called *campaigns* to configure and deploy gamification methods on a platform with the aim of maximizing the student engagement and attendance. On the other hand, the students are the targeted participants i.e. the main players. The platform was designed and developed using the agile development methodology [21], where all the main stakeholders—including the students and the lecturers—were involved in the development, defining and shaping the *user stories* and deriving the *requirements*.

2.1. Requirements and Design

While the need for the system in general was motivated by lacking student engagement and attendance, the detailed requirements were derived via user stories, following interviews and pretend-scenarios involving lecturers, university administrators and students. These revealed that all parties were interested in the system and willing to invest in its success. On the lecturer side, it was pointed out how they would like to be in control and able to tailor the campaigns to their needs. The administrators highlighted the need for ease of use, and the students iterated that the gamefulness and fun aspect should not be overshadowed by the formalities of student attendance. Based on the user stories, the following requirements were collected and classified by priority, using the MoSCoW method [7], as shown in Table 1.

Must have	Gamification web admin interface (lecturers, admin staff). Gamification web student portal (students). Database schema design to model campaigns and badges. Web API for developing client apps. Provision of mobile apps for student use (Android/iOS). Ability to view detailed attendance progress. Ability to view badges and achievements progress.
Should have	Students able to browse campaigns available for their registered modules. Leaderboards with best students in module, school, university.
Could have	Live leaderboard on a public university screen providing data regarding Overall progress of the group competitions (best module performance etc.)
Would have	Intelligent feedback that will message the user based on his/her current attendance status and the overall progress compared to previous data. Progression hints that will inform the user of potential achievements or badges he/she is close to achieve. Custom, student-defined notifications for important events/achievements.

Table 1. Requirements for the gamification engine classified by priority

2.2. Campaigns

Core to the system design is the concept of *Campaign*. This concept encodes all the required properties of running and updating campaigns, which are themselves elementary units of *games*. For instance, the following are simple examples of campaigns:

- Within module X (e.g. "Introduction to Programming"), attendance is measured at the individual's level and a leader-board indicates the best three performances. Within the same module, a special achievement is defined as "attending 5 or more consecutive sessions".
- Within programmes Y and Z (e.g. "Computing" and "Web Design"), attendance is measured at a group level and a leader-board lists the performance of each programme's complete set of modules.

The development of this system assumes that an attendance system is already operational. The *game* itself is essentially fully dependent on student attendance and that's the only control the students have over the set *campaigns*. The high-level design of the system is illustrated in Figure 1.

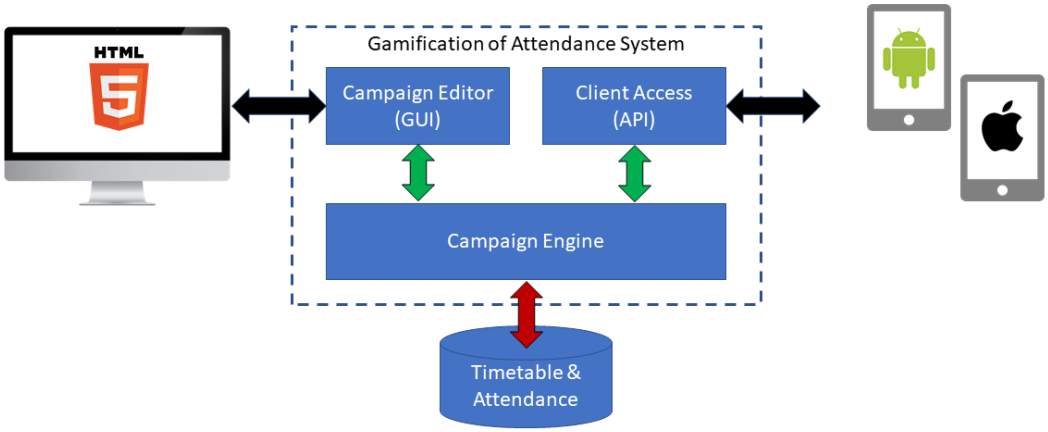

Figure 1. A high-level view of the attendance gamification system design.

The system builds on the *Timetable & Attendance*, a legacy system that handles student attendance monitoring, storage and management. In our case study—and in the evaluation—attendance is monitored using an NFC-based system. The students scan their cards to special registration points in the classrooms, as they enter them right before their sessions. This kind of self-managed NFC-based attendance is common in many higher education institutes and has been the focus of research studies in the past [3, 5].

The core gamification logic is implemented by the *Campaign Engine*. This is responsible for monitoring the active campaigns, updating the game elements (i.e. leaderboards, achievements, etc.) and allowing interfacing with the clients used by the stakeholders (i.e. lecturers and admin staff to monitor and edit the campaigns, and students to interact with the gamification elements). This component is described in more detail in section 2.3.

The *Campaign Editor* is a web-based app allowing the involved staff, such as lecturers and admin staff, to create new campaigns as well as view, edit and monitor existing ones. To ensure ease of use, the app provides pre-configured campaigns which the lecturers can easily reuse with no or little change. These are discussed in more detail in section 2.4.

Core to the interaction among these components is the *campaign* concept. A campaign essentially encompasses all the necessary parameters for running an instance of a *game*. This includes metadata, such as its creator, a title and a description, as well as core data which

allow it to be interpreted by the Campaign Engine, such as the period in which it is active, and importantly the method by which the achievements are computed. A simplified example showcasing the *campaign* model is illustrated in Listing 1.

Listing 1. Example illustrating the structure and main features of the JSON-based *campaign* model—note that some text is omitted to avoid cluttering

```
{
  "campaigns" : [

    {
      "uuid": "361652b8-5267-4dcc-a00f-651212e51671",
      "type": "campaign ",
      "created-by": "someone@example.com",
      "name": "Best attendance in AB1234",
      "description": "A competition-like challenge <...> awarded a badge",
      "valid-from": "2016-09-26",
      "valid-until": "2017-04-31",
      "update-rankings": "daily",
      "game-type": "competition",
      "game-domain": "module",
      "game-domain-value": "AB1234",
      "game-group-by": "person",
      "badges": [
        {
          "badge-id": 1,
          "badge-name": "Best attendance award",
          "badge-url": "https://<...>/11/1415490092badge.png",
          "badge-calculation": "max-attendance(1)"
        },
        {
          "badge-id": 2,
          "badge-name": "Second best attendance award",
          "badge-url": "https://<...>/11/1415490092badge-2.png",
          "badge-calculation": "max-attendance(2)"
        }
      ]
    },

    ...
  ]
}
```

2.3. Campaign Engine

The Campaign Engine is the core component of the information system realizing the gamification aspects of the attendance system. Its operation is determined by the individual campaigns. As all campaigns are logically separated, the engine can safely handle them in sequence, in any order. Essentially, the role of the Campaign Engine is to interact with the attendance system, take the updates (i.e. student attendance and non-attendance entries) and use them to compute the most updated state of each campaign. The results of the computations are stored in JSON-formatted files themselves (denoted as *campaign-states*) and are cached for efficient recall by the campaign editor as well as by the clients.

As there is no need for real-time computation of the leaderboards, it suffices to schedule the Campaign Engine to execute only periodically (typically hourly). During these updates, the campaign states are computed and cached using the pseudo-code listed in Algorithm 1. Effectively, this algorithm specifies that for *all* active campaigns, fetch the relevant data from the attendance database system, and use it to compute the new rankings. Based on these intermediate results, compute the new standings with respect to achievement completion for each badge.

Algorithm 1 Pseudo-code for updating the game state (leader-boards, badges, etc.)

```
for all Campaigns do
  if Campaign IS active then
    Read the Campaign properties.
    Fetch relevant data from the database.
    Compute the student/module/programme rankings.
    for all Badges do
      Update the list of Badge awardees as needed.
    end for
    Produce a new campaign status message and cache it for quick access.
  end if
end for
```

Finally, the computed results are cached for quick access.

2.4. Campaign Editor

The *Campaign Editor* is required to enable the following functionality:

1. Allow authorized staff (e.g. lecturers and admin staff) to *create* new, or *edit* existing campaigns,

2. Provide assistance in the form of *help pages* and *ready-made templates* for creating new campaigns, and,

3. Enable authorized staff to *monitor* running campaigns, and provide insights about their effectiveness.

We have created a prototype campaign editor in the form of a web-app to create new campaigns, as well as view, edit and monitor existing ones. To ensure ease of use, the web-app provides pre-configured campaigns which can be easily reused with no or little change.

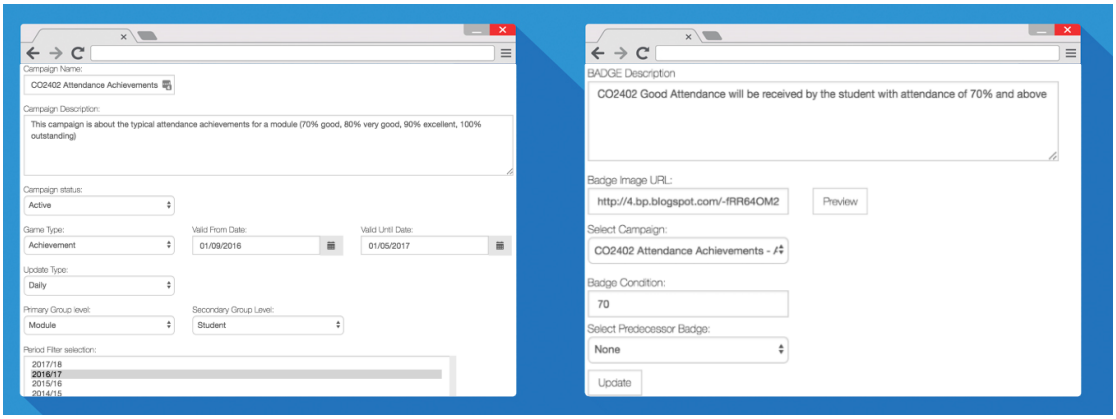

Figure 2. The web-based campaign editor. Among other fuatures, it enables users to set up a new campaign (left) or define new badges (i.e. achievements) and associate them with an existing campaign (right).

Two sample screenshots are shown in Figure 2. The left-side one illustrates a view where a new campaign is defined and configured, while the right-side one depicts the process of defining and configuring a new badge (i.e. achievement) and associating it with an existing campaign.

2.5. Clients and Client Access API

Web-based and native Android clients were developed for the students. These clients provide a set of services–including personalized timetables for the students–along with the gamified view for attendance monitoring.

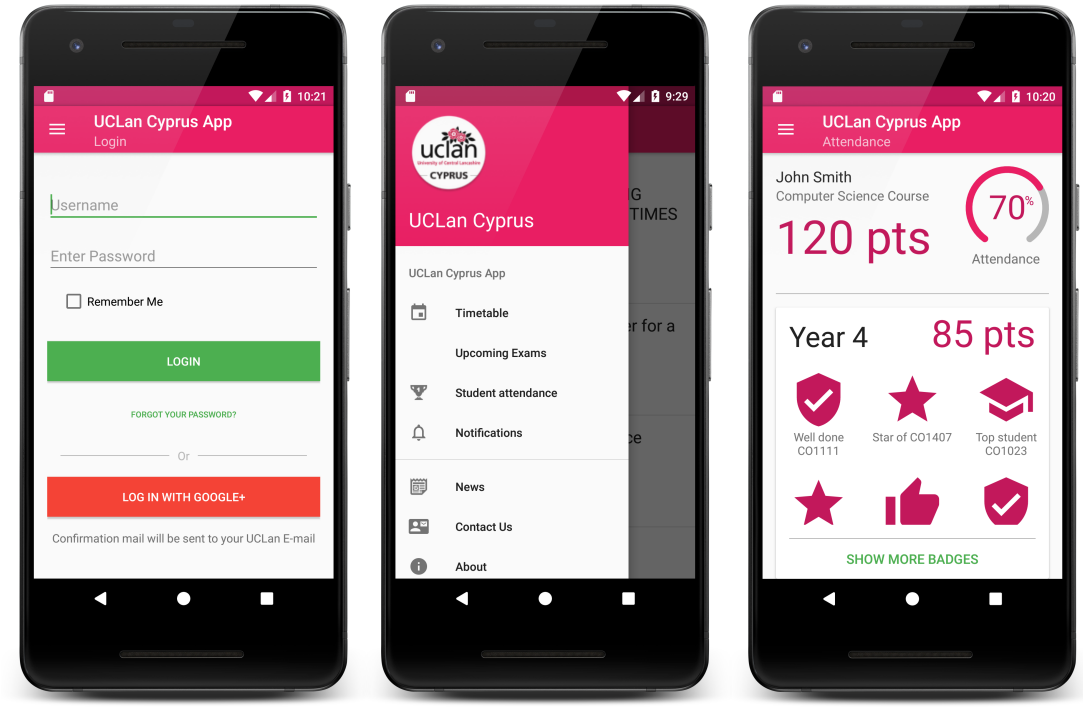

Figure 3. The mobile prototype built for Android. The screenshots illustrate the UI for logging in (left), the menu for the various options–including the gamified *Student Attendance* (middle), and a sample screen of a student's attendance status (right).

In order to provide a personalized view, the app requires user authentication to allow access to the personalized services. Student authentication utilizes the standard authentication mechanism used for other online services as well (leftmost screenshot in Figure 3).

The app provides additional services adding value and further encouraging use by students. These services include personalized timetables, exams schedule, and notifications—in addition to the gamified student attendance view. Additional services are provided even without authentication, such as university news and useful contact information. These are made available via a universally-accessible menu (see middle screenshot in Figure 3).

Last and most notably, the app provides a view displaying the student performance in terms of attendance, both as a simple summarized score (e.g. 120pts or 70% attendance) as well as various achievements unlocked. This provides the core of the gamified approach and aims at behavioral change of students by providing further incentives to not miss any sessions. An example of this view is illustrated in Figure 3 (rightmost screenshot).

In both cases (i.e. the Web-based admin system and the Android-based app), interaction with the core system is via a REST-ful API [20]. This allows for a consistent and platform-independent interface, enabling the following functionality (among other):

- **/getTimetableByStudent** and **/getTimetableByLecturer** allowing to access individual timetable information from the perspective of both students and instructors, and
- **/getAttendanceByStudents** allowing to access attendance records and achievement completion from the perspective of students.

3. Evaluation

To evaluate the effectiveness of this system, we have collected and analyzed attendance data over two years, covering the periods (i.e. academic years) preceding the deployment of the gamified system, as well as the one immediately after its deployment. This section presents the procedure we followed to collect data, as well as a summation of the data and the results obtained from its analysis.

3.1. Procedure

The study took place at the University of Central Lancashire, Cyprus (UCLan Cyprus) and covered two academic periods, from September 2015 to May 2016, and from September 2016 to May 2017, using a total of 250,374 attendance records from 948 distinct students. The study parameters are summarized in Table 2.

Study parameters	
Academic periods covered	September 2015 to May 2016, and September 2016 to May 2017
Number of distinct students included	948
Number of attendance records covered	250,374

Table 2. Study Parameters: period covered in the study and size of data

The attendance records were obtained through the *Student Attendance Monitoring* system which has been used at the university both before and after the deployment of the gamified system. The attendance system tracks student physical presence in the classroom and serves by providing information both to the students themselves, as well as to the lecturers and the course leaders. Its main purpose is to allow the students to reflect on their performance in light of their measured attendance, and to help the academic staff by providing an early warning for disengaging students.

Attendance is recorded when students scan their university cards at the beginning of teaching sessions–we refer to these records as *scanned attendance*. In the case of a malfunction in the scanning mechanism, students could request to have their attendance recorded manually, by contacting the university administration team. The admin team could then register attendance records manually, using a dedicated web-based interface–we refer to this as *manual attendance*.

Each attendance record contains a status code ranging from -1 to 5, indicating if the record represents an absence (-1), presence (0 for scanned attendance and 1 for manual attendance) or justified absence (2-5 for various reasons of justified absence, such as sick-leave with a doctor's note, etc.) For the purpose of this study, only attendance records with a status of -1, 0 or 1 were used and a new calculated field was created: ATTENDANCE. This field was computed via a direct translation of the status: -1 to "A", denoting an absence, and 0 or 1 to "P", denoting a presence.

Besides the student information, the attendance records were further augmented with the corresponding module (e.g., CO2402 Advanced Programming) for which the record was scanned for. Additionally, in the cases where a module belonged to a single programme (e.g., CO2402 belongs to the Computing programme), we were able to aggregate the results at the *programme* level and later on, at the *school* level. For each level (i.e., *student*, *module*, *programme* and *school*) and for each academic period, we recorded the attendance over the total records, yielding the attendance percentage. To avoid statistical bias with small samples in higher dimensions than *student*, we ignored any cohorts with less than 5 students. Finally, we computed the increase or decrease in attendance performance by comparing the attendance percentage of

2015/16 versus that of the following year, 2016/17.

Students were given access to the web and mobile-based environments and were encouraged to engage with it and view their attendance (as individuals and as groups) at any time they wished. Both environments were able to present to the student the following information:

- The average attendance across all enrolled modules,
- The actual attendance for each module, and,
- The badges that the student (or their group) achieved.

3.2. Participants

The attendance records were drawn from a total of 948 active students of the University of Central Lancashire Cyprus. The students were allocated to 71 university programmes from three schools. The dataset containing the attendance records was anonymized before it was made available for analysis, and information regarding gender and age was not shared. As mentioned earlier, small cohorts were also removed from the dataset to preserve anonymity and avoid biases in the data.

3.3. Analysis of Results

The following hypothesis was formulated for the purpose of our research:

> **H1:** Students attendance will increase (i.e. improve) as a result of introducing the gamified system.

In our analysis, we studied the impact of attendance over four dimensions: *student*, *module*, *programme* and *school*), as described in section 3.1. The results are summarized in Table 3.

School	**Impact**
School of Sciences	6.09%
School of Business & Management	3.75%
School of Law	26.60%
Min	3.75%
Max	26.60%
Average	12.15%

Module	**Impact**
Count (total)	229
Count (positive)	138 (60%)
Average (positive)	19.25%

Student	**Impact**
Count (total)	500
Count (positive)	249 (50%)
Average (positive)	15.80%

Table 3. Impact measured over refined dimensions: School, Module, Student

We observe that all three participating schools had an increase in overall attendance of 12.15% on average, with the Law School showing a significant increase of 26.60%. Even if the latter is viewed as an outlier, the other two schools demonstrate an increase in attendance.

The results at the *programme* dimension lead to a similar conclusion. Out of the 21 programmes in total, 16 reported an increase in attendance with an average of 11.03% while only 5 reported a decrease with an average of -2.26%. We also observe that the School of Law programmes (i.e., ULLAWS140, ULLAWS100, ULLAWS580, ULLAWS183, ULLAWS180) had an increase in attendance of over 25%, with three modules over 30%. The programme-based results are summarized in Table 4.

Programme	**Impact %**	**Programme**	**Impact %**
ULACCO134	-1.84	ULACCO140	2.04
ULBABA140	0.03	ULBABA134	-0.47
ULEGLG103	3.80	ULHOTO100	3.75
ULHOTO134	2.21	ULEDLE583	2.68
ULBUAD581	-4.59	ULBUAD583	3.92
ULLAWS140	31.57	ULLAWS100	25.11
ULLAWS580	32.52	ULLAWS183	30.48
ULLAWS180	21.05	ULCOMP100	3.99
ULMATH100	1.08	ULPSYC134	8.94
ULPSYC100	-2.30	ULSEXS140	3.23
ULCYBS580	-2.12		

Median	3.23%
Min	-4.59%
Max	32.52%
Average	7.86%
Average (positive)	11.03%
Average (negative)	-2.26%

Table 4. Impact on attendance at School, Programme, Module and Student dimensions, with summarizing notes

For brevity, we do not provide the individual results for the module and student dimensions but rather the aggregated results only. We observe that 60% of all modules have reported an increase in student attendance with an average increase of 19.25% and similarly 50% of the students have an average increase of 15.80% in attendance.

While we do not really have a clear indication for why different modules exhibit different engagement (as manifested in the *impact* column), it can be partly attributed to how students perceive and accept computing technology (for instance computing students might be naturally more interested in using this system compared to law students) and partly on differences to the individual instructors (as some might be naturally more successful in engaging students).

4. Discussion and Related Work

Behavioral change is not a new topic but it is now receiving a lot of attention, especially in mass media. The literature is abound with examples of using behavioral change, from governments legitimately trying to benefit their citizens [12], to scandals involving companies pursuing to affect political outcomes using data which were collected in a way that was considered to be at the least "*inappropriate*" [2].

In a book he co-authored, Thaler discusses the power of "nudges" [24], and argues that "*three principles should guide the use of [behavioural change aiming] nudges: i. All nudging should be transparent and never misleading. ii. It should be as easy as possible to opt out of the*

nudge, preferably with as little as one mouse click. iii. There should be good reason to believe that the behavior being encouraged will improve the welfare of those being nudged" [23].

We used these principles as a guide when we were designing the gamified attendance system. Students were informed of the system in a transparent manner. They were also informed about its implications (no measures would be taken against anyone no matter the percentage of attendance, as this was an individual matter anyway). Students could not formally *opt out* but in reality they could simply ignore it (in practice many did not even get the app or accessed the gamified interface). Third, we believe–and are supported by data [16]–that improving attendance will positively affect students' performance, and likely their welfare as well.

Gamification has already been applied in many contexts, often with positive results [11, 25]. For instance, it has been applied for social good, where the most popular example of gamification was *Fold-It*, an online collaboration game aiming at predicting protein structures, developed by researchers at the University of Washington [8]. This gamified, crowd-sourcing application attracted a lot of attention when it achieved to solve a previously long-standing puzzle in just ten days [15], effectively helping in the fight against HIV [19].

Another breed of gamified platforms aims at encouraging behavioral change, either at a personal or at a wider level, similar to ours. For instance, these include setting up and coordinating community-wide efforts which offer mutual, often regional or even worldwide benefit (e.g. an environmental benefit). These are sometimes called Collective Awareness Platforms and have received wider recognition, e.g. the European Commission has allocated funding that explicitly targets the formation and advancement of such platforms [1].

Another example is "Watts-up?", an online application that collects and presents live data related to energy consumption [10]. The users of the application compete for the highest reduction in consumption. Their social network friends' performance is used for motivating their further reduction. Similarly, the Social Electricity app aims to "*motivate citizens towards pro-environmental behavior*" [13, 14]. This is achieved by means of comparisons with the corresponding electrical consumption of their friends (e.g. Facebook circle), as well as with the total consumption in the area they live in. Through the comparison, the consumers contextualize their energy behavior and thus are encouraged to take steps to reduce their electricity consumption and consequently their carbon footprint.

A similar, attendance-related gamification project has also taken place at Kingston University and its results were documented in [6]. In their project, Caton and Greenhill applied gamification to increase student attendance and improve the team dynamics of a computer game development module. Their work is based on the familiar concepts of reward and penalty, i.e. desired behavior such as high attendance is rewarded, and undesired behavior such as low engagement or poor teamwork is penalized.

Finally, it should be noted that Gamification has also been criticized as merely *marketing hype*. In a widely cited post, Ian Bogost specifically argued that "[...] *gamification is marketing bullshit, invented by consultants as a means to capture the wild, coveted beast that is videogames and to domesticate it for use in the grey, hopeless wasteland of big business, where bullshit already reigns anyway.*" [4] Nevertheless, many of the methods commonly classified under the *Gamification umbrella* are commonly used with success, especially in the enterprise world [17].

5. Conclusions

In this paper we describe a novel information system which uses gamification for behavioral change, and specifically to improve student engagement and attendance. The system builds on a custom designed model of *campaigns* and realizes a client-server architecture. Its implementation includes both Web and Android-based clients to be used by students, as well as a Web-based interface for administrators. The system is evaluated in terms of applying it to a real-world setting in a university, involving nearly a thousand students and hundreds of thou-

sands of attendance records. The attendance performance of students is assessed at an individual level, as well as at a group level, i.e. at the *module*, *programme* and *school* levels.

By comparing the attendance recorded before and after the introduction of the gamified system, we were able to derive some early results and insights into the impact of the system. While the data was rather limited–especially in terms of duration–we were able to observe a notable positive impact in terms of improved student attendance.

For the future, we aim to improve the gamified aspects of the system–especially its appeal to students–using student-driven case studies. Also, we aim to collect and process data over a longer period, covering multiple consecutive academic years, and aim to observe how individual campaigns can perform differently, and perhaps understand the underlying dynamics. Lastly, we aim to further refine our analysis, e.g. by segmenting our data according to gender and age, in an effort to identify possible causation or other influencing parameters.

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