A Software System to Support Student Engagement in Academic Courses

Darina Dicheva, Keith Irwin, and Christo Dichev

Winston-Salem State University, Winston Salem, NC 27110, USA
{dichevad,irwinke,dichevc}@wssu.edu

Abstract. One of the most challenging problems faced by educators today is how to increase students' engagement in academic courses, especially in STEM (Science, Technology, Engineering, and Mathematics) disciplines. Motivation is a major driver of engagement in learning, particularly in optional (not required) learning activities where learners have to plan and coordinate their learning process without instructors' intervention. Lack of motivation and inability to engage learners are among the top and most frequently cited barriers for learners' engagement in such activities. Among the various approaches that have been proposed to improve students' motivation, gamification has garnered significant attention from the educational community. While research has shown that well-designed gamification may improve student motivation, appropriate software to support educational gamification is generally missing. This paper describes a powerful customizable software platform that can be used for gamifying academic courses. It can support both instructors who seek to gamify their courses as well as researchers in educational gamification.

Keywords: IT in Education, Educational Gamification, Student Engagement.

1 Introduction

In recent years, gamification – the use of game design elements in non-game contexts [1] – has seen rapid adoption. The rising interest in it is reinforced by behavioral studies, which reveal that a core set of intrinsic motivators exists in all of us: the desire to improve, to achieve, to direct our own lives and to connect with others. These motivators can be stimulated by the right experience.

Several studies have been published arguing that gamification can be successfully implemented in educational contexts to improve student motivation [2]. However, a main obstacle that instructors face is the lack of educational software that can be used to support course gamification. This causes a significant burden on instructors who want to apply gamification to their courses. From another side, some studies have reported non-significant, mixed or contradictory results of applying educational gamification [2]. Improving our understanding regarding the sources of such conflicting results entails the need of a platform that can facilitate the creation of gamified learning activities and support experimental studies in varying contexts. To address these two problems, we have implemented a course gamification platform [3] that supports the

use of popular game design principles and mechanisms in the organization of academic courses.

In this paper, after a short introduction of educational gamification, we summarize the system functionality and exemplify its use for gamifying one particular course. The theoretical foundation of the work and more details are given in [3].

2 Educational Gamification and Its Challenges

Gamification in learning uses elements drawn from game design to make learning activities more motivating and engaging and to improve learning outcomes. While the interest in applying gamification in education is growing, given its potential to enhance and sustain students' motivation [4], research on how to support gamified learning does not follow this trend. This is a consequence of the fact that gamification as a multidisciplinary research domain integrates elements of information technology, human-computer interactions, human motivation, and task design thus requiring knowledge from multiple disciplines.

The use of games in an educational setting is not a new idea. However, the concept and implementation of gamification in the educational sector has been introduced recently [5]. Several studies revealed various barriers, concerns, and support needs regarding the gamification of learning. The gamification design and development process require special skills that go beyond the knowledge of the average instructor. On the one hand, designing and developing a gamification solution is different from developing a game [6]. Entertainment is not the aim of gamification; its main goal is to drive desired user behavior [7]. This involves accounting for a variety of user behaviors, motivations, and requirements of different stakeholders such as learners and instructors. Therefore, there are high entry barriers to design adequate tools to support educational gamification [8]. Educators with little or no training in information technologies are very likely to create "bad gamification" with little or no effect on learning. Furthermore, the gamified learning tools involved might not be mature enough to support true gamification that is able to provide meaningful gamification experiences. The lack of customization is another criticism for applying gamification in education [9]. Most current gamified learning tools serve average students and are hardly engaging for high-performing or left-behind students. In customizable gamification platform the gamification experience can be adapted to various learners' and instructors' preferences.

The currently available support for educational gamification is limited. There are some general gamification platforms, such as Badgeville, Hoopla, Bunchball and PugPharm, but their typical approach is packing selected gamification techniques in 'one size fits all' systems, responding to the needs of enterprises with varying organizational structures. Education involves activities different from those in the corporate world, which entails the need for dedicated platforms. There are several gamification platforms targeting education such as ClassCraft, Rezzly, and ClassDojo, but they are designed with K-12 education in mind with a focus on class management and reward systems. At the university level, there are limited number of gamification platforms offered such as Kahoot and Gradecraft [10]. Kahoot, however, is basically a platform

for creating simple gamified quizzes. Gradecraft, on the other hand, is focused on grading and student choice of learning paths through a course (which is not always practical for STEM courses). To support gamification, educators often use LMS, such as Moodle, Blackboard, or Canvas, which provide some gamification elements. However, the gamification features offered by most LMS are limited to basic elements such as points, badges, leaderboards, and levels, and their behavior is hard-coded. Finally, game mechanics have been inserted in some previously developed online learning systems, mainly by converting grades to scores, introducing points for some activities supported by the system, and using the points for leaderboard ranking and/or rewarding specific badges. Such superficial 'gamification', often called 'pointification', is solely based on extrinsic enablers and empirical studies show that it does not lead to improved motivation of students [11]. The lack of proper general support for gamifying learning in higher education motivated us to design and develop a holistic course gamification platform, OneUp [3], which is aimed at both facilitating the gamification of academic courses and fostering experimental research on gamifying learning.

3 The Course Gamification Platform

3.1 Platform Design

To design a course gamification platform that meets learners, teachers, and researchers needs, we had to come up with a general specification of how an academic course which uses the platform should be organized and structured with regard to its content and learning activities and how gamification elements should be linked to the underlying course structure. There were three major requirements for the platform design:

1. Content independence: to be both course independent and learning activities independent.
2. High configurability: to allow instructors to choose not only what game elements they want to use in the gamified learning activities but also how these elements work.
3. Data analytics-driven GUI: to provide an intuitive, data analytics-based view of students' and class performance.

Meeting the first requirement suggested that specific learning content should not be built within the system. Instead, like in LMS, the instructor should enter the course content and/or activities which they want to gamify. Meeting the second requirement suggested that the provided gamification support should be configurable, the gamification elements should not have a predefined behavior, and the system should be opened for adding new gamification features. The third requirement concerned the provision of rich visual representation of the results of data-driven analyses of the student learning activities that could be used to provide learners and teachers with timely feedback for optimizing their experience.

These requirements suggested the implementation of a component-based architecture utilizing the MVC (Model-View-Controller) architectural design pattern. In

addition, to achieve a highly configurable gamification platform, which could be specialized to reflect specific customer (instructor) requirements, it needed to be modeled after the concept of a software product line [12]. Thus, the game elements needed to be designed as loosely coupled components in the system which work independently.

The software was implemented in Python using Django, a Model-View-Controller (MVC) Python Web Framework and a PostgreSQL database. The interface was written in HTML5 and JavaScript, allowing the platform to be used also from mobile devices.

3.2 Platform Description

The major blocks of the platform are an authoring tool, a gamification tool, a configuration tool, and a learner modeling/learning analytics tool. The authoring tool enables the instructor to create *challenges* and *activities* in their course shell. Challenges consist of problems, which are automatically graded by the system, and can be *warm-up challenges* for self-learning and self-assessment or *serious challenges* for graded course tests or quizzes. The problems can be static or dynamic. *Static problems* are such, for which the correct solution is specified at the time of entering the problem in the system. These include multiple choice questions, multiple answer questions, true/false questions, fill-in-the-gap questions, and matching questions. *Dynamic problems* are intended primarily for STEM-related courses. They are short computer programs which use a random seed to generate a unique instance of a particular question and then grade the correctness of the answer submitted to that question. This allows variants of the same problems to be used by different students on a test, or by the same student to practice. The automatic grading of program questions is essential for implementing the 'immediate feedback' game design principle. Somewhat in between the static and dynamic problems are the Parson's problems. These are a type of code completion problems in which the learner must place given mixed up code lines/blocks in a correct order. By enabeling the platform to dynamically generate problem instances, it can make available a sufficient pool of exercises of a particular type for students to practice.

In addition, the platform supports *activities* that can be any course related activities which are not automatically graded by the system. For example, these can be labs, assignments, student presentations in class, participation in a course-related event, etc., for which the instructor assigns points. These points are entered in the system and could be used in course gamification.

The gamification tool consists of gamification rules and a rule engine, which is the heart of the gamification platform. Gamification rules are what link the learning activities defined in the system to the game design elements. For example, a rule can specify the conditions upon which a badge is awarded, or course bucks are earned. In fact, rules combine the learning activities with the game design elements in a coherent gamified course. The rules are in the form of production rules:

if_satisfied (action, condition) then offer (incentive),

where action denotes any measurable process performed by a learner and incentive denotes any award supported by the system. For example,

IF a student completes 8 challenges from a single topic THEN award them a badge.

The instructors specify the rules in an appropriate interface. By defining rules with different conditions and game elements that are awarded upon these conditions, instructors can induce different forms of enjoyable experiences, such as, an experience of curiosity, surprise and novelty or experience of choice/autonomy as illustrated below:

One of the next five consecutive days is lucky: if you solve three problems in the lucky day you earn 3 course bucks.

The configuration tool supports two kinds of configuration: one related to the course structure and another to the gamification features to be used in the particular course. The course configuration includes specifying the course topical structure, the learning objectives (skills) targeted in the course, and the milestones and activities planned for the course (with their corresponding points), but none of these is required. The gamification related configuration includes choosing the game elements to be used in the course along with specifying gaming rules for them. The system currently supports the following game elements: XP points (based on challenge, skill, and activity points), goals, levels, progress bar, badges, various leaderboards, skill board, virtual currency (VC), avatars, random surprises, duels, and callouts. Fig. 1 shows screenshots from two different student interfaces displaying some of the elements used in a gamified course.

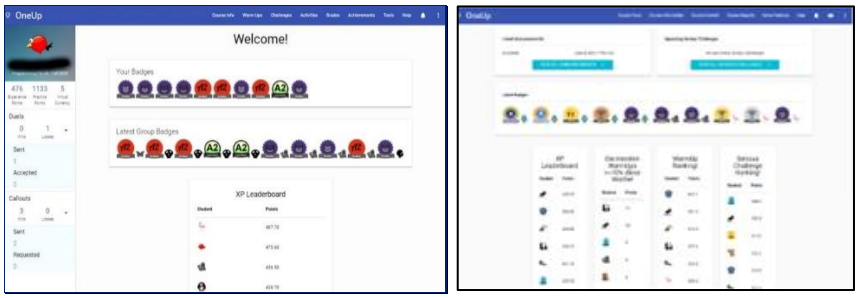

Fig. 1. Screenshots of OneUp student interface: two variants of course homepages.

The learner modeling/learning analytics tool utilizes learning-related information that can be derived from the data collected in the system. This data include: the number and category of awards acquired, and VC obtained, high/low/mean challenge points, activity points, skill points, practice sessions' starting times and length, number of warm-up challenges attempted and the corresponding success rate, problems avoidance, and problems abandonment. All these shed light on student learning and skill progress, targeted skills, persistency, problem solving habits, and meaningful use of VC.

When the derived information is related to learners' goals and the progress toward these goals is tracked, meaningful feedback loops can be created that can sustain desired behavior.

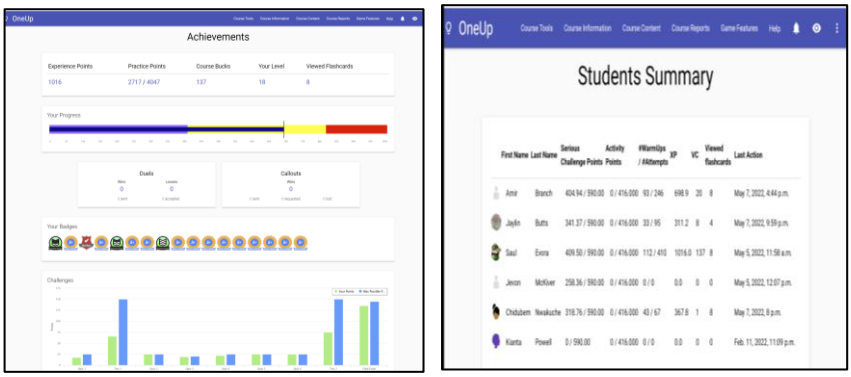

Fig. 2. A student's dashboard (left) and an instructor's student summary page (right).

The learning analytics tool supports a comprehensive learning dashboard that allows students to see aggregated data on their performance. It also provides analytical support for the instructors enabling them to view the performance of each student and the class performance across various metrics. Fig. 2 shows screenshots displaying a student's Learner Dashboard and an instructor's Student Summary page.

In the next section we provide an example of how the system can be used for gamifying an academic course.

4 An example of an Academic Course Gamification

The creation of a new course in OneUp includes a sequence of steps none of which is required: specifying the course topics, targeted skills, and milestones; specifying course activities; entering warm-up challenges for student practice and serious challenges for course assessment (if desired); and selecting game elements to be used in the course along with creating gaming rules for them. This example describes the gamification of a sophomore-level computer science course taught by one of the authors.

The instructor specified the course topics and for each of them entered warm-up challenges in the authoring interface. She also created two categories of (not automatically graded) activities - Labs and Homework. Next, the instructor configured the gamification features to be used in the course. The selected features included: avatars, badges, XP leaderboard, virtual currency (VC), and duels. These selections were set in the instructor's Gamification Configuration page. While nothing more had to be done for the use of avatars and duels in the course, the use of badges and VC required specifying rules governing the issuing of the awards. The distinguishing feature of OneUp is that instructors can link learning activities to the selected game elements in the way they want. They do this by specifying the conditions under which the awards will be given to students. If virtual currency is used, two sets of rules must be specified: *earning rules* and *spending rules*. When students satisfy the condition of an earning rule, they receive the specified course bucks. When a student accumulates some amount of VC in their VC account, they can spend it in the *course shop*. Table 1 shows some of the

badges and associated rules specified by the instructor and Tables 2 and 3 - some of the created VC earning rules and spending rules.

Table 1. Sample badges used in the course.

Badge	Description
	Take for the first time warm-up challenge with a score >= 80%.
	Get the highest score in the class for Assignment 1.
	Complete at least one warm-up challenges a day for 5 consecutive days.

Table 2. Examples of earning rules.

Rule Description	VC
Taking a new warmup challenge with a score >= 80%	1
Attending 5 consecutive classes	1
Complete 5 or more warm-ups on a topic with a score >= 80%	3

Table 3. Examples of spending rules.

Rule Description	VC	Limit
Get one day homework deadline extension	10	2
Drop the lowest lab score	6	3
Get a surprise gift from the instructor	20	1

The instructor has experimented with different game rules and selections of different gamification elements. The results of the conducted studies, described elsewhere, confirmed the positive impact of gamification on student engagement.

5 Conclusion

As motivation influences students learning behavior, it is a critical factor for students' success [1]. However, fostering motivation reliably remains an elusive task [4]. Hence, selecting effective strategies to engage and motivate students remains a challenge for the educational community. As part of the efforts for finding a way to foster motivation, gamification has emerged as a potential strategy to boost students' motivation toward learning activities by employing design principals inspired by games [1, 2]. While it is gaining popularity in education, available sources providing practical guidance on how to gamify learning are scarce and fragmented. In addition, there is no adequate software support that instructors can use to gamify their courses and researchers – to explore the impact of gamification in educational settings. The contribution of the presented here

work is towards filling this gap by creating a course gamification platform that can be used for both gamifying academic courses and promoting empirical research. Being highly configurable, it can provide support to both instructors and researchers.

The gamification platform described here has been and continues to be used in several courses across different universities and countries and has proven to increase student motivation to participate more actively in the gamified courses.

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