Gamification as a Service for Formative Assessment E-Learning Tools

Robert Clarisó, Joan Arnedo-Moreno, David Bañeres, Santi Caballé, Jordi Conesa, David Gañán
Estudis d'Informàtica, Multimèdia i Telecomunicació
Universitat Oberta de Catalunya, Rambla del Poblenou 156, Barcelona
Email: {rclariso, jarnedo, dbaneres, scaballe, jconesac, dganan}@uoc.edu

***Abstract*—Formative assessment tools can benefit from the addition of gamification elements, as stronger engagement may generate further learning opportunities. However, adding gamification elements to such tools may require a significant development effort and leads to few opportunities for re-use, e.g. among different e-learning tools within the same course or degree. In this paper, we describe a platform for offering gamification elements as a service to any formative assessment tool. We describe our experience in an introductory course for Digital Circuit Design in a Computer Science Degree.**

I. Introduction

Gamification is the application of game thinking and game mechanics in non-recreational activities. Gamification in the educational setting has recently received a lot of attention due to its perceived potential [1], [2]. It should not be confused with *serious games*, where a set of skills is developed by playing a custom-designed game. While the effects of gamification in education are not fully understood [3], [4] many works have tried to tackle its benefits to student engagement.

A particular area where increased engagement can benefit learners is the acquisition of *practical skills*, as it may be necessary to exercise them repeatedly before mastering them. Educators have already devised a mechanism to provide detailed feedback during this repeated exercises: *formative e-assessment tools* [5], which provide automated feedback to learners after each activity. However, performing a repetitive task may reduce student motivation, and gamification is precisely oriented towards improving that engagement. Thus, it makes sense to focus gamification efforts on promoting the use of formative assessment tools.

Designing a suitable gamification strategy [6] for a given formative assessment tool is key to its success. However, one of the challenges for the developers of these tools is the effort required to *implement* those game mechanisms:

- The complexity of using information from outside the scope of a single assessment tool or even a single course, e.g. keeping track of the progress of a student along an entire degree.
- The need to re-define or re-implement gamification features in a variety of tools, without the ability to reuse those features.

Assessment tools may be implemented in a variety of languages and technologies, and they may be deployed either as stand-alone tools or in a variety of Learning Management Systems (LMS), e.g. Moodle or proprietary platforms. Hence, it is not possible to provide gamification features by means of a software library or framework: a *service-based* solution [7] is required.

In this paper, we describe a web-based platform called ICT-FLAG that provides gamification services to formative assessment tools. These services can reduce the development effort required to integrate gamification strategies within an existing formative assessment tool. As a side effect, users of the tool also gain other benefits provided by the ICT-FLAG platform, namely *learning analytics* [8].

There are several companies and platforms offering gamification as a service through APIs or cloud-based solutions. However, they do not target formative assessment tools, and thus have no context regarding the semantics of the information they are using. Moreover, their main focus is not on reducing development effort but flexibility (to target a wide variety of application domains). As a result, they may require complex customizations to define the gamification strategy and extensive modifications of formative assessment tools in order to take advantage of the information provided by the gamification service's API (e.g. displaying badges, reaching a new level, etc.).

Paper organization. The remainder of the paper is structured as follows. Section II presents an overview of the ICT-FLAG platform, with a special focus on its use for gamification. Then, Section III describes how this platform has been used in the context of an introductory course on Digital Circuit Design. Section IV discusses related work. Finally, Section V presents the conclusions and discusses future work.

II. The ICT-FLAG platform

ICT-FLAG [8]–[11] is a web-based education platform that offers learning analytics and gamification services to students, lecturers and managers. Its goal is leveraging all the information produced by formative assessment tools in order to provide relevant feedback to each user profile and improve the student engagement.

A. Architecture and design principles

Information is provided to the ICT-FLAG platform by the formative assessment tools themselves. When a relevant *event* takes place within the assessment tool (e.g. a student submits a solution, a submission is evaluated) this information is

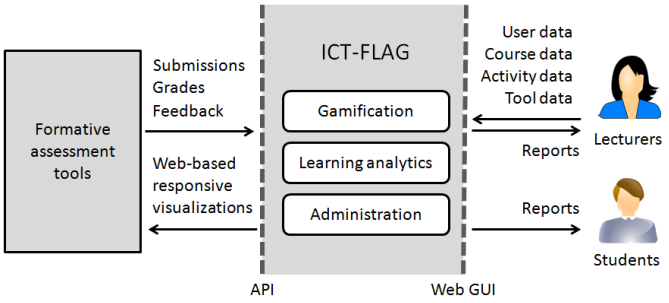

Fig. 1. Architecture of the ICT-FLAG platform

submitted to ICT-FLAG through a dedicated API. Students and lecturers can also access the ICT-FLAG platform through a dedicated web interface. This interface can be used to (a) view reports about individual and group performance and (b) manage information about the students, courses, e-assessment tools and assessment activities. Figure 1 depicts this architecture.

ICT-FLAG attempts to support the widest range of formative assessment tools, and thus, makes as few assumptions as possible about their technology or architecture. For instance, formative assessment tools may be *client-based* (e.g. self-assessment exercises embedded in HTML course materials), *server-based* (e.g. a remote computer receives submissions from the students and check their solution) or *client-server* (e.g. the student uses a client tool to prepare the solution in its computer and submits it for assessment to the server). This is a very important distinction as server-based tools can be reached to send notifications of relevant events, while this is not possible for client-based tools. Thus, as a design principle ICT-FLAG expects formative assessment tools to interact using a *pull* strategy: tools send and request information from/to ICT-FLAG without expecting the platform to initiate any communication.

From the point of view of gamification, formative assessment tools must send *queries* in order to gain information about the current state of a gamification element (e.g. scoreboards, badges, ...). In order to facilitate the implementation of gamification elements, the answers to those queries are not offered through an API, but through a web-based visualization. This visualization is *responsive* to provide support for mobile-based formative assessment tools. Thanks to this design decision, instead of processing the results and adding this information to the tool's GUI, tool developers can simply relay the web visualization to users, simplifying the development effort. These benefits have been validated in previous case studies where learning analytics services were offered to formative assessment tools [8].

B. Gamification in ICT-FLAG

While there are many potential game mechanics and rules, in this context, we restrict ourselves to those that are based on the use of formative assessment tools. For each submission, ICT-FLAG provides information like dates (the date when it was submitted and, if available, the date when the student began working on the submission); the assessment tool being used; or the feedback given to the student by the tool (e.g. a grade). This information can be aggregated considering many different criteria: by student, by course, by tool, by date, by feedback (correct vs incorrect), ...

To take advantage of this data, ICT-FLAG includes a set of re-usable gamification elements that can be included in the web visualizations, e.g. individual and group performance metrics, goals, progress bars, ... These elements consume the assessment data received from formative assessment tools, and are therefore updated automatically based on student activity.

As a limitation, so far ICT-FLAG provides limited support to facilitate the *customization* of these gamification elements: the choice of suitable elements, their arrangement in a visualization and their link with suitable metrics. That is, this customization must be performed by the lecturer within the ICT-FLAG platform and requires some knowledge about its internal architecture and data model.

Part of our ongoing work is the definition of a customization GUI where users can define the desired game mechanics in a user-friendly way. The goal is allowing the definition of a set of *rules* of the form `IF condition THEN action` (triggered when a new event is reported by a formative assessment tool) or `WHEN condition THEN action` (triggered when a condition is met, either due to an event or due to a temporal milestone being reached). The action could be, for instance, issuing a badge, updating the progress towards a goal, starting a new quest, ...

A challenge in this customization process is striking the proper balance between the expressivity and complexity in the definition of gamification elements. A very expressive language could require a lot of effort from the lecturer to define even trivial gamification mechanics, thus rendering the use of gamification impractical. On the other hand, if this rule language is too simple it may restrict its application to trivial usage scenarios.

III. Sample Application

We have applied the ICT-FLAG platform and its gamification elements in the context of an introductory Digital Circuit Design course offered within a Bachelor's degree in Computer Science. This course is provided in a fully-online methodology through the virtual campus of Universitat Oberta de Catalunya. In the following, we discuss the characteristics of this course and how gamification has been applied in this context.

This is the first course of the degree where students learn about digital systems. Students learn several basic competences such as circuit design, optimization and analysis. Three distinct formative assessment tools are used during this course, each corresponding to one of these areas:

- *VerilCirc*, a tool for assessing digital circuit design exercises (selecting and connecting the logic gates that perform a given computation).

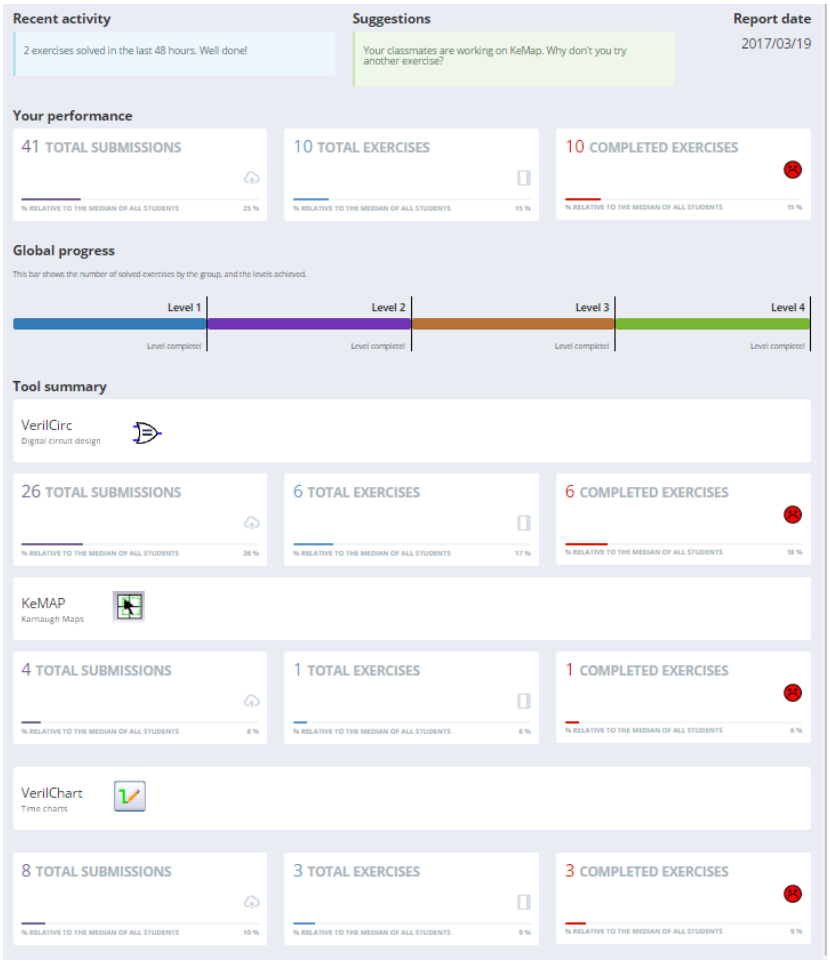

Fig. 2. Visualization of gamification elements for the Digital Circuit Design Course

- *KeMAP*, a tool for evaluating activities for the simplification of Boolean functions using Karnaugh Map minimizationv technique.
- *VerilChart*, a tool for circuit analysis exercises featuring timing diagrams.

The defined goals for gamification in this course were the following:

- Motivate students to solve additional exercises, as the key competences of the course are best acquired by applying them in practice and improve through experience.
- Encourage students to start practising as early as possible, as in an e-learning context a late start may lead to a drop-out.

To achieve these goals, the following game design principles and mechanics were used:

- *A collaborative challenge with a reward*: We offered a set of benefits that could be unlocked by achieving a collective goal (reaching a number of solved exercises among all students). Several thresholds provided greater benefits with increased challenges, with the use of *onboarding* (the first threshold was very easy to reach). A progress bar tracked the current status with respect to the goals.
- *Status and feedback*: We tracked the progress of the student both individually and with respect to the rest of peers in the group in terms of number of attempted exercises and number of exercises solved correctly. There was no leaderboard but the student knew at all times his standing in comparison with his peers. Students with a poor performance were not given detailed information to avoid discouraging them.
- *Quests related to recent activity*: Recent activity was compared with that of other students in the group and, if the student was late with respect to his peers, suggested activities would be proposed.

Figure 2 shows an example of the visualization of the gamification mechanics provided to students. Notice that all the information shown to students can be extracted from the information logs within the ICT-FLAG platform. Similar game mechanics could be defined for other assessment tools and courses, reducing the development effort.

Regarding the results, the use of gamification has had a positive impact in the number of exercises solved by the students of the course. In previous semesters, students solved on average 15-16 exercises, a metric which has increased above

20 with the application of gamification. Students perceived the information provided by gamification as "useful" and "a motivation to continue practising". Regarding the features that need to be improved, student requests focused on the assessment tool rather than the gamification elements, demanding more detailed feedback and a more extensive documentation.

IV. Related work

A. Gamification in formative assessment

Nowadays, many formative assessment tools include gamification elements in order to boost engagement [12]. The most basic game mechanics include points, badges and leaderboards, but other tools also include other types of game mechanics such as virtual goods or currencies [13].

Unfortunately, the development of these gamification elements is tailored for specific tools. While this allows a great degree of flexibility and control, it does not facilitate reuse in the development of new tools and constrains game mechanics within the scope of a single course.

The approach presented in this paper has several limitations with respect to a custom development of gamification elements for a specific tool. First, custom development may allow leveraging information beyond what is captured by the ICT-FLAG platform. For instance, a tool may be able to harvest information about the process followed by the student to create the solution, or gather additional details about the characteristics of the problem statement. Second, they may offer real-time feedback and push-based mechanics, i.e. where the tool takes the initiative in interacting with the users. Finally, custom development may offer a more refined user experience, improving the integration of the gamification elements within the tools' GUI and protocol. However, we believe that reducing the cost of integrating gamification elements may benefit tool designers who do not have sufficient resources to perform a custom development.

B. Gamification as a service

Several companies offer gamification services through APIs or cloud platforms, e.g., IBM[1] (service deprecated in Oct. 2016), SAP[2], BadgeVille[3], GetBadges[4] or Bunchball[5]. These services are primarily intended for business with the goal of motivating workers, users and/or clients, and they offer complex rule engines to define the intended game behavior. Even though they could be applied in an educational setting, this is not their primary target.

Another notable mention is the Open Badges[6] initiative started by Mozilla in 2011 and currently managed by the IMS Global Learning Consortium. This standard provides technical solutions to issue, publish, store and share badges.

[1]https://www.ibm.com/developerworks/community/groups/community/gamification/

[2]https://cloudplatform.sap.com/capabilities/collaboration/gamification.html

[3]https://badgeville.com/

[4]http://getbadges.io

[5]http://www.bunchball.com/

[6]https://openbadges.org

In an academic context, Odin [14] is a gamification service for learning activities which supports points, badges and leaderboards. However, all the rules and game logic must be implemented in the tools invoking Odin's API, and there is no support for offering visualizations of this information.

V. Conclusion

In this paper, we have presented an approach for reducing the cost of adding gamification elements to formative assessment tools. As an additional advantage to tool authors, they can also benefit from additional features of the ICT-FLAG platform, i.e., learning analytics.

A challenge of this method is providing flexibility and usability in the definition of game rules and elements. As future work, we plan to define a graphical *domain-specific language* (a concept similar to [15]) to allow the definition of gamification strategies and elements.

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