Smart gamification: Exploring the application of gamification in smart learning environments

Alejandro Ortega-Arranz, Eduardo Gómez-Sánchez, Miguel L. Bote-Lorenzo, Sergio Serrano-Iglesias, Juan I. Asensio-Pérez and Alejandra Martínez-Monés

GSIC-EMIC Research Group, Universidad de Valladolid, Valladolid, Spain

Abstract

Smart Learning Environments are conceived as environments able to understand the student needs and context, and to propose adapted informal learning activities that might involve physical and virtual elements. However, SLEs can potentially fail in engaging students to perform such generated tasks as they are not part of the learning design and they might not be assessed by the teacher. Therefore, considering the positive effects observed in other educational environments, gamification is proposed to increase the student engagement and participation in such informal activities. Nevertheless, the gamification of activities that are not part of the learning design and which are generated on-the-fly becomes a difficult task as the gamification design needs to be created on the run without the intervention of the teacher. To make this process meaningful, the cornerstone is the adequate use of Learning Analytics and Learning Design information. This work-in-progress paper introduces a technological architecture supporting this type of gamification, and Smart GamiTool, a prototype of a smart learning environment supporting the orchestration and enactment of smart gamification.

Keywords

Smart Gamification, Smart Learning Environment, Learning Analytics, GamiTool, Teachers

1. Introduction

Smart Learning Environments (SLEs) are educational environments able to understand the student needs and context, and to automatically adapt their learning experience [1, 2]. For instance, Hwang [3] proposes the use of SLEs to generate automatic informal tasks (*e.g.*, the creation of a concept map), associated to real entities near the position of the learners (*e.g.*, trees), and which are related with the contents learned in the formal context (*e.g.*, school). Therefore, in this example, the course content (*i.e.*, theory about trees) and the students' physical location are the input variables that personalize the suggestion of informal tasks. However, SLEs involving physical and virtual spaces can potentially fail in engaging students to perform such informal tasks as they require physical activity, are not part of the formal learning design and they will not be assessed by the teacher [4]. Given this situation, gamification is proposed to help overcome such issue (*i.e.*, to increase student engagement) based on the results observed in other educational and non-educational environments across physical and virtual spaces [5].

LAS4SLE @ EC-TEL 2021: Learning Analytics for Smart Learning Environments, September 21, 2021, Bolzano, Italy
alex@gsic.uva.es (A. Ortega-Arranz)
0000-0002-8167-7157 (A. Ortega-Arranz)

Gamification is usually defined as the use of game design elements (*e.g.*, rewards) and structures (*e.g.*, stages with increasing difficulty) in non-game contexts (*e.g.*, education) [6]. Nevertheless, it seems difficult to gamify activities that are not part of the learning design as configured by the teacher, and which are generated on-the-fly by SLEs. Considering the previous example, many gamification design questions arise such as *how to automatically gamify a task that is not known beforehand? how to promote the visits to unknown entities with gamification?* or, *how many points should be given for successfully performing such task?* Therefore, we propose to denote as *Smart Gamification* those gamifications that need to understand the context (*e.g.*, informal tasks proposed, desirable student actions within the informal tasks) to automatically create "meaningful gamification designs" on-the-fly able to promote the purposes for which the gamification is used (*e.g.*, increase student engagement). To this end, Learning Analytics (LA) play a fundamental role in *smart gamifications*, providing gamification systems with information to understand the context, and therefore, as an additional input variable to create such meaningful designs [7]. Accordingly, SLEs and gamification systems need to define pre-established contracts considering the supported computer-interpretable LA information. Therefore, the underlying RQ guiding this work is *How can topic-independent smart learning environments be gamified using LA?*

To the best of our knowledge, there exist gamification systems able to adapt different game elements according to the learners' engagement and preferences [8]. However, the gamified activities are designed by the teachers and/or the researchers (*i.e.*, known beforehand), and although the game elements are different for the different student profiles, the gamified activities are similar to all students. Additionally, there exist several SLEs with gamification capabilities (*e.g.*, programming [9], e-health [10], mathematics [11]). Nevertheless, these SLEs are topic-specific, and have the gamification rules hard-coded, thus skipping the on-the-fly gamification of SLE-generated activities. The work-in-progress presented in this paper describes a scenario highlighting the usefulness of the proposal (Section 2); presents a technological architecture that supports the gamification of SLEs using LA (Section 3); and, outlines a set of conclusions and ideas for future research (Section 4).

2. Smart Gamification: A Scenario

Taking back the scenario given by Hwang about SLEs for learning about trees [3], in this section we describe how students might react to the gamification of such scenario:

Rose and Anna are two secondary school students using a SLE that proposes informal activities related to nearby physical entities that have a connection with the contents taught in the classroom (*e.g.*, trees, historical buildings). In particular, this month, Rose and Anna learn about trees, including the different types of trees according to their leaves (*i.e.*, evergreen and deciduous trees). Informal activities (*e.g.*, creating a concept map, answering a quiz or watching a video related to the nearby entity) are generated weekly by the SLE considering the student knowledge about the topic (obtained through the results of the weekly quizzes) and their physical position. In this case, the difficulty of the physically-located informal activities is proportional to the student knowledge level on this topic.

In order to complete the informal activities, students have to get physically close to the proposed entities and complete the associated task, as suggested by the SLE. Although the activities are visible in the SLE app from any student location, they are only unlocked once students are close to the entities. In case the student location is out of the boundaries of any related entity, the SLE will propose the completion of the tasks without the need of being close to any entity[1].

This week, Rose is struggling with the features of deciduous trees, and was suggested with an informal activity involving 5 different trees near her location. At the beginning, Rose is not engaged to perform the proposed informal activity because they will not be assessed by the teacher. Nevertheless, she likes the possibility of earning rewards, including being ranked in a leaderboard with other friends, customizing her avatar in the SLE and earning virtual cash that can be redeemed for course privileges (*e.g.*, deadline extensions, unlocking contents). Therefore, motivated by the possibility of earning such rewards, she decides to visit the physically-located entities and complete the proposed tasks. Additionally,since students can earn +20 redeemable points when performing the activities with other students, Rose called and convinced her friend Anna to do the activities together. At this point, for each reached entity they will earn 50 redeemable points, additional to the extra points earned by successfully completing each of the associated tasks (*e.g.*, successfully answering quizzes, watching 100% of videos). At the end of the activity, Rose and Anna have a total number of 500 redeemable points that they could use to buy a new avatar and an additional attempt for the next course quiz.

In this scenario, we have visualized how the gamification might affect the behavior of certain students (*e.g.*, fostering students to get close to the entities and to complete the informal task with other students). However, *which LA were needed to automatically perform the gamification of such activities during course run-time?* The next section presents an eventual architecture that would support the implementation of this type of gamification.

3. Smart Gamification: Components and LA

In order to understand the data exchange needed for smart gamifications, we have synthesized SLEs and gamification systems into their main components. On the one hand, SLEs are usually based on three components [4] (see white boxes in Fig. 1): *(i) Sense*: collects information about students' context (*answers in weekly quizzes*); *(ii) Analyze*: generates higher-level indicators and profiles learners based on such indicators (*determines the level of knowledge for the different topics*); and *(iii) React*: provides personalized tasks based on students' profile (*physically-located quizzes, concept maps and videos*). On the other hand, gamification systems can be also decomposed into three similar components (see gray boxes in Fig. 1). Borrowing the names from SLEs: *(a) Sense*: monitors student actions within gamified activities (*answers to physically-located quizzes, concept maps and videos*); *(b) Analyze*: compares student actions with predefined gamification conditions (*100% score in quizzes, 100% video visualization*); and *(c) React*: issues the rewards to those students satisfying the gamification conditions (*virtual cash*).

The main feature of smart gamification derives from the fact that gamification conditions and rewards are generated by the system, while in traditional gamifications, teachers or pro-

[1]It should be noted that these rules are not part of the learning design. Instead, they constitute the "smartness" of the SLE and therefore, other rules could be applied.

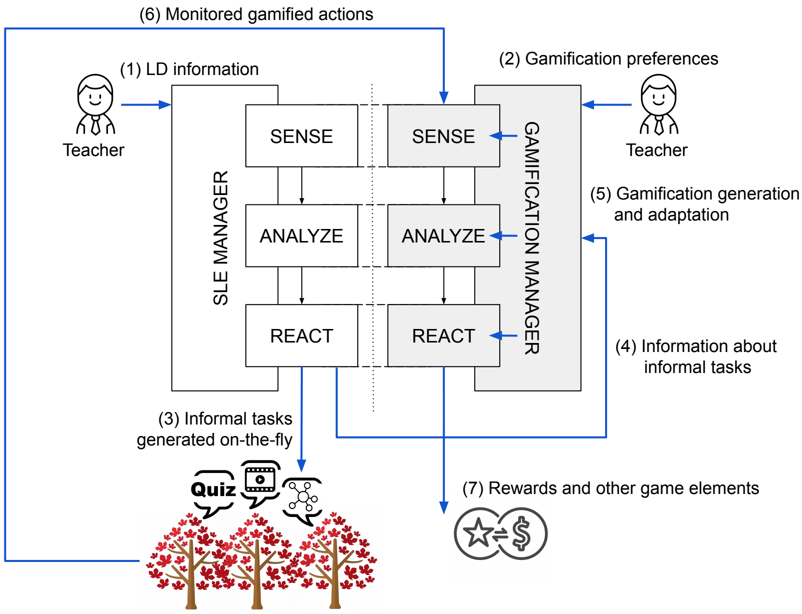

Figure 1: High-level architecture and data-flow for smart gamifications.

grammers are responsible of configuring the actions to be monitored, their thresholds (*i.e.*, gamification conditions), and the reactions (*i.e.*, gamification rewards). In Figure 1, the *Gamification Manager* will be the architectural element in charge of reading the different input variables that automatically will create and update the gamification design. Therefore, smart gamifications should at least contain the aforementioned functionality (*e.g.*, sense, analyze, react) either in an integrated environment where the "smart" and "gamification" components are shared for both purposes (*integrated gamified SLE*) or in decoupled systems with different components (*SLE + gamification system*).

In the scenario before, the teacher of the course configured the formal learning design of the course, including the quizzes and their topics, that later were used by the SLE to understand the knowledge level of the students (see (1) in Fig.1). Additionally, the teacher expressed in the gamification system that he wants to foster collaboration between students with the smart gamification (2). During course enactment, Anna and Rose were monitored and evaluated by the *SLE-Sense* and the *SLE-Analyze* components respectively to understand their level of knowledge regarding the different topics of the course. As a basic example, this level of knowledge could be interpreted considering the average score obtained in the same-topic quizzes during the last week ($low \leq 40\% < medium \leq 80\% < high$).

Since Rose obtained a score lower than 40% for the *deciduous trees* topic, she was provided with informal activities as considered by the *SLE-React* component (3): complete quizzes, concept maps and videos being next to 5 deciduous trees near her location. At this moment, the proposal of informal activities needs to be reported to the *Gamification Manager* in order to understand which actions are susceptible to be gamified (4). This interaction should include:

1. Any SLE configuration that may be useful to tune the gamification design. In the previous

scenario, this information could regard the maximum number of informal activities that can be suggested to one student in such week (*i.e.*, for low knowledge students, 5 activities). This information grants that all the students will have access to the same rewards although the conditions to earn them may vary according to their level of knowledge.

2. The number and type of generated tasks per student (in the scenario before, Rose had 5 physically-located activities: 2 answers to questionnaires, 2 video watches, and 1 concept map creation). This information enables the system to know the gamification conditions that can be applied to the proposed informal activities. Thus, apart from actions common to all types of activities (*e.g.*, open the activity, complete the activity, complete the activity before a specific date), the gamification system can personalize the gamification according to the activity types (*e.g.*, achieving high score for quiz-based activities, watching more than 50% of a video).
3. The location of the informal activities. This information allows the gamification system know where the gamification system must monitor the student actions. It should include the tool where the reaction is performed (*e.g.*, H5P), the identifier of the resource (*e.g.*, video ID: 345) and the credentials to query their analytics (*e.g.*, teachers' token).

Every time that the gamification system receives new information from the SLE, the gamification manager should create or update the gamification design for the informal activities triggered. As an example applicable to the previous scenario, and considering the gamification preferences of the teacher, the gamification system will issue as maximum as 600 redeemable points (RPs). In the case of Rose (*i.e.*, a student with 5 triggered activities), she will get a maximum number of 100 RPs per activity (+20 RPs if the activity is performed together with another student). Getting into more detail, 50% of points will be issued when reaching the physical entity and the remaining 50% if the student successfully completes the different activities (*i.e.*, 100% score in quizzes, 100% video visualization, concept map with at least 10 elements) (5)[2].

Once the gamification design is created (or updated), this information is transferred to the other gamification components to: start monitoring the triggered activities (6); analyze if the conditions are satisfied; and, reward the students (7). In the case of Rose, she got 500 RPs as the sum of 3 activities completed successfully: *(100+20) * 3 = 360 RPs*, and 2 activities that were visited but unsuccessfully completed: *(50+20) * 2 = 140 RPs*.

In order to demonstrate the feasibility of this proposal, we have developed a prototype of an integrated gamified SLE: *Smart GamiTool* (see Figure 2). Smart GamiTool is based on the original gamification tool GamiTool[3], incorporating basic smart functionality as described in the scenario, proposing personalized reactions that involve physically-located entities (annotated in Open Street Map[4]), videos from YouTube[5], multiple-choice questions from Casual Learn[6] and course privileges (*e.g.*, unlocking content). At design time, Smart GamiTool enables teachers to configure certain gamification features (*e.g.*, game elements) that will be later considered as input variables for the creation of the gamification design during course enactment.

[2]It should be noted that as different rules could be applied to obtain the *knowledge level* of the students and to trigger the reactions, different rules could be also applied to generate and update the gamification designs.

[3]GamiTool: *https://www.gsic.uva.es/gamitool/*, last access: September, 2021.

[4]Open Street Map: *https://www.openstreetmap.org/*, last access: September, 2021.

[5]YouTube: *https://www.youtube.com/*, last access: September, 2021.

[6]Casual Learn: *https://casuallearnapp.gsic.uva.es/*, last access: September, 2021.

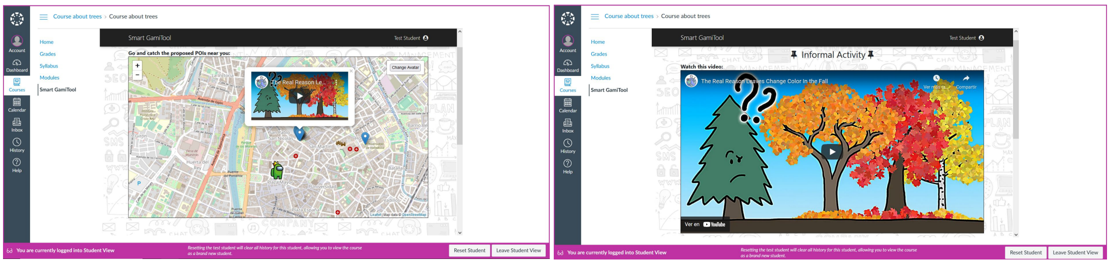

Figure 2: Screenshots of Smart GamiTool in Canvas LMS: (a) student interface with gamified and physically-located activities about deciduous trees, and (b) student interface with the same activities in the virtual space (students without nearby entities).

4. Discussion and Next Steps

This paper proposes the use of multiple data (*e.g.*, teacher inputs, LA generated by SLEs) to inform the design of smart gamifications that can be generated in smart learning environments involving physical and virtual spaces. Our initial hypothesis is that smart gamifications can foster the participation and completion of informal activities generated by SLEs without the need of teachers or programmers configuring the on-the-fly gamification designs. Thus, we presented a high-level architecture and its data flow to support this type of gamification. Additionally, we started the development of a system implementing such architecture and data flow: Smart GamiTool.

In the short term, we aim to finish the development of a functional prototype, and evaluate the generated gamification designs for different inputs (*e.g.* activity types, topics, game elements). Then, we plan to use the prototype in real scenarios with secondary school students from where we could get an idea of the temporal and cognitive implications for teachers, and its effectiveness to foster student participation in informal activities generated by the integrated SLE. In the medium term, we will consider the integration of more complex rules to increase the "smartness" of the integrated SLE, including the gamification manager. This could involve the integration of Smart GamiTool with external SLEs such as SCARLETT [12], and the consideration of other variables affecting to the design of effective gamifications such as the student preferences [8].

It seems interesting to highlight that the addition of gamification strategies in smart environments might brings some pedagogical concerns that will need attention. For instance, there could be students failing on purpose the activities configured as part of the formal design to trigger easier informal activities (proposed by the SLE). Therefore, students could get easily more rewards than those students being proposed with more difficult activities. This would be another interesting point to explore in the foreseen empirical studies.

Acknowledgments

This research was funded by the Spanish State Research Agency (AEI) and the European Regional Development Fund (TIN2017-85179-C3-2-R, PID2020-112584RB-C32); and by the European Regional Development Fund and the Regional Government of Castilla y León (VA257P18).

References

[1] R. Koper, Conditions for effective smart learning environments, Smart Learning Environments 1, 5 (2014). doi:10.1186/s40561-014-0005-4.

[2] J. M. Spector, Conceptualizing the emerging field of smart learning environments, Smart learning environments 1, 2 (2014). doi:10.1186/s40561-014-0002-7.

[3] G.-J. Hwang, Definition, framework and research issues of smart learning environments-a context-aware ubiquitous learning perspective, Smart Learning Environments 1, 4 (2014). doi:10.1186/s40561-014-0004-5.

[4] B. Tabuenca, S. Serrano-Iglesias, A. Carruana Martín, C. Villa-Torrano, Y. Dimitriadis, J. I. Asensio-Pérez, ..., C. Delgado Kloos, Affordances and Core Functions of Smart Learning Environments: A Systematic Literature Review, IEEE Trans. Learn. Technol. 14 (2021) 129–145. doi:10.1109/TLT.2021.3067946.

[5] D. Dicheva, C. Dichev, G. Agre, G. Angelova, Gamification in Education: A Systematic Mapping Study, Journal of Educational Technology & Society 18 (2015) 75–88.

[6] S. Deterding, D. Dixon, R. Khaled, L. Nacke, From Game Design Elements to Gamefulness: Defining Gamification, in: Proc. 15th ACM Int. Acad. MindTrek Conf.: Envisioning Future Media Environ., 2011, pp. 9–15. doi:10.1145/2181037.2181040.

[7] A. Ortega-Arranz, A. Martínez-Monés, J. I. Asensio-Pérez, M. L. Bote-Lorenzo, GamiTool: Towards Actionable Learning Analytics Using Gamification, in: Companion Proc. 11th Int. Conf. Learning Analytics & Knowledge, 2021, pp. 215–223.

[8] S. Hallifax, A. Serna, J.-C. Marty, E. Lavoué, Dynamic gamification adaptation framework based on engagement detection through learning analytics, in: Companion Proc. 11th Int. Conf. Learning Analytics & Knowledge, 2021, pp. 202–2014.

[9] I. Deliyannis, P. Kaimara, Developing Smart Learning Environments Using Gamification Techniques and Video Game Technologies, in: Didactics of smart pedagogy, Springer, 2019, pp. 285–307. doi:10.1007/978-3-030-01551-0_15.

[10] P. Di Bitonto, E. Pesare, V. Rossano, T. Roselli, Smart Learning Environments Using Social Network, Gamification and Recommender System Approaches in e-Health Contexts, in: Smart education and smart e-learning, Springer, 2015, pp. 491–500. doi:10.1007/978-3-319-19875-0_44.

[11] A. Cisneros, Y. Hernandez, A. Martínez-Rebollar, J. Ortiz, H. Estrada Esquivel, Study on Intelligent Tutor Systems based on Gamification, in: Proc. 13th Congreso Mexicano de Inteligencia Artificial, 2021.

[12] S. Serrano-Iglesias, E. Gómez-Sánchez, M. L. Bote-Lorenzo, Connecting formal and informal learning in Smart Learning Environments, in: 2021 International Conference on Advanced Learning Technologies, 2021, pp. 439–441. doi:10.1109/ICALT52272.2021.00139.