Gamification in Assignments: Using Dynamic Difficulty Adjustment and Learning Analytics to Enhance Education

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Abstract

This paper discusses the opportunities for gamification and dynamic difficulty adjustment based on multimodal learning analytics in assignments. Altogether this covers a broader term of personalized education, which is getting more attention among the researchers in recent years. The difference of this work from other similar researches is that it suggests combining several domains to achieve better results: gamification (in order to improve student's motivation and involvements), and dynamic difficulty adjustment. All this is made possible by applying multimodal learning analytics and creating useful learning dashboards for the teachers.

Author Keywords

gamification; dynamic difficulty adjustment; personalized learning; multimodal learning analytics

CCS Concepts

•Human-centered computing → **Empirical studies in HCI;** *Participatory design; Visualization design and evaluation methods;* **•Applied computing** → **E-learning; Interactive learning environments; •Computing methodologies** → *Machine learning approaches;* **•Theory of computation** → *Convergence and learning in games;*

Gamification: is the use of game elements characteristics (such as: points, badges, progress bars, meaningful stories, profile development and etc.) in non-game contexts [10].

Learning analytics: the collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs [a].

Balanced game: stimulates the learning without pushing the players too far or not enough. It keeps them in the flow state, where the player feels challenged, but neither bored nor frustrated [8]. Ideally, the difficulty of any task should be defined by the current user.

[a] http://www.solaresearch.org/

Introduction

Continuous advancement of the educational process is essential in order to keep up with the fast-paced digital world and keep students well motivated and involved. That's why increasing students' motivation is an important task [30]. A lot of researches suggest adding gamification, for example [10, 15, 25, 30]. This research proposes enhancing the educational process by introducing personalized gamified assignments, based on the previous students' experience. The experience and skills levels are proposed to be measured using multimodal learning analytics. The result of which will be displayed on well-organized learning dashboards, for the future use by teachers. Also gathered data will be used for training the machine learning algorithm for classification and dynamic difficulty adjustment.

The main goal of the research is to prove that the educational process can benefit from introducing personalized gamified assignments with dynamic difficulty based on multimodal learning analytics. There have been already some work done, both in the theoretical and practical domains. Two papers with the results of the research are published as conference proceedings [22, 23], and both of them have been invited to be published ad journal articles.

Research background

Serious games and gamified assignments are well suited for data analysis. They produce highly individualized data trails that reflect the player's personal choices, behaviors, and performances and can be analyzed to explore how users play and learn [31]. One of the main goals is to measure and set up the balance in the gameplay. Multimodality can be achieved by analyzing data from several sources (timing, speed, gaze, heart rate) [1, 2, 24, 32, 33]. The dynamic difficulty might be achieved by changing the number of hints, the code given to students in upfront, the amount of awarded points, etc. In regard to motivation, the impact of gamification was studied, and results are described in [9, 22, 29]. Although the traditional tool to assess serious games is questionnaires, several authors have addressed non-disruptive tracking [6, 16, 21] or custom analytic tools [19, 12, 34].

The downside of most of the researches is that they do not pay enough attention to the educational domain and do not measure how much knowledge was actually delivered. Research in the field of learning analytics mostly presents local use cases. Such experiments are useful for future researches, but not all of them could be generalized or transferred to other contexts [31]. That's why there is a strong need in generic frameworks. Additional problems arise when we design the tools for using and representing the gathered data poorly [13]. This can lead to a situation when these tools distract users attention. We can consider dashboards as one of the possible solutions to the problem of appropriate data visualization. The well-designed dashboards should improve decision-making by supporting cognition and perception. A possible solution to improving the usability of the dashboard is described in [23]. Research [35] provides a list of major learning dashboards. Combined with data analysis, the learning dashboards can lead teachers to discover students' performance patterns, predict problems and find motivational elements [26, 36]. The information about the factors which affect learning is one of the most investigated questions in education [28].

Recent literature review

During the literature review, the main attention was paid to the existing research objectives of the area so far, and the main trends for future researches. Each question has been studied for all relevant areas: multimodal learning analytics, dynamic difficulty adjustment, gamification. It is clear that

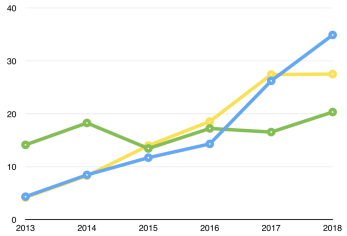

Figure 2: Annual distribution (2013-2018) of research papers in the areas of multimodal learning analytics (blue), dynamic difficulty adjustments (green) and gamification in education (yellow).

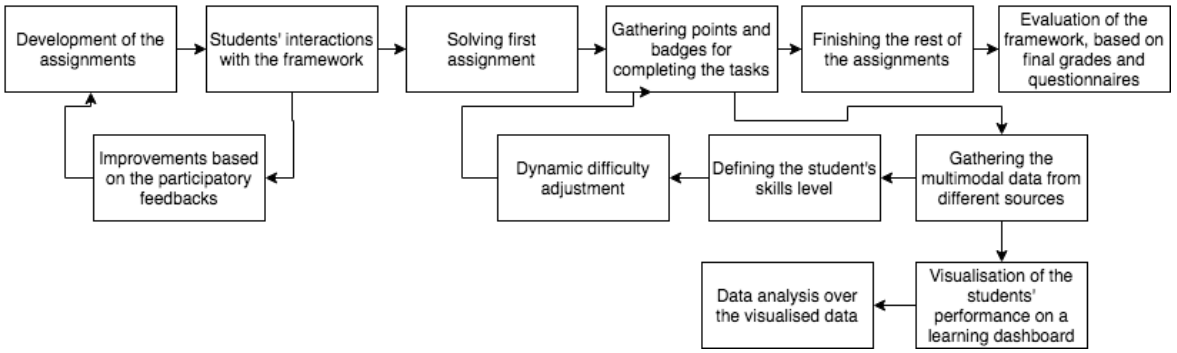

Figure 1: General structure of the proposed framework, displaying main stages of the workflow.

Similar PhD theses: *Gamification in an Online Course: Promoting Student Achievement through Game-Like Elements* [17]; *The Gamification Inventory : An Instrument for the Qualitative Evaluation of Gamification and its Application to Learning Management Systems* [3]; *Gamification of Mobile Educational Software* [4]; *Personalization Through the Application of Inverse Bayes to Student Modeling* [18]; *Modeling learning behaviour and cognitive bias from web logs* [27]; *Dynamic difficulty adjustment* [20].

interest in all these areas is still growing (Figure 2). While analyzing papers for the multimodal learning analytics, the main interest was in the captured modalities [14]. Another analyzed area was gamification in education [5, 7, 11, 29]. As stated in [32] current researches do not pay enough attention to deep learning algorithms utilization and also there is a clear need to find easier ways to gather data. Some of the papers mentioned the lack of the analysis of final exam grade. Also, mainly papers do not mention the possibility of dynamic difficulty adjustment of the gamified tasks, which is going to be the part of primary research in the current thesis.

All similar PhD theses which have been published in the recent years cover just a part of the questions raised in the current paper. But the innovation of this research is in the combination of several areas. None of the works studying gamification tried to apply dynamic difficulty adjustment on the assignments. And the researches about dynamic difficulty usually do not study the educational effect. The framework which is going to be developed as the part of this research would solve these gaps.

Personalization of assignments

This research is going to use the framework with personalized assignments in order to analyze the influence of gamification and dynamic difficulty adjustment on students' motivation and engagement. The experiments are going to take place while teaching Web Development course at the Brno University of Technology and also with the students of Electrical Engineering course in KU Leuven. Participating in the study with the help of this framework versus the regular way of completing the assignments will be completely voluntary and will not affect the final grade. Figure 1 shows the main functional structure of the proposed framework.

The development of this framework will adopt participatory design principles. Gathered data will be displayed to teachers on well-designed learning dashboards. Evaluation of the introduced framework will be done from two sides. Firstly, students and teachers will receive questionnaires asking about their subjective experiences. Then, at the end of the year, the final grades of the students in the experiment would be compared to the ones from the control group. This will help to get the objective results.

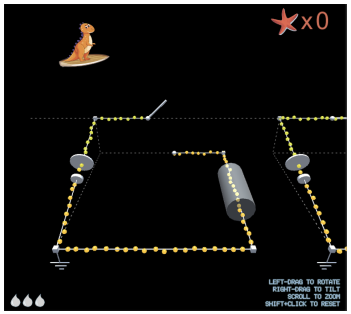

Figure 4: Example of a level in Current Surf.

To be discussed:

if teacher's role isn't decreased

if game isn't a distraction

if assignments with a variable difficulty lead to honest evaluation

if making it open source wouldn't help students to hack it

BombsQuery - gamified programming assignments

The developed assignment was already given to students in the Web Development course at Brno University of Technology. It is in the form of web platform named *bombsQuery* (Figure 3) and is aimed to teach the basics of jQuery. The narrative is going around the need to clean the field from all bombs, marking them with the help of white flags. To make it work, students need to write a particular part of the jQuery code, as described in the task. Apart from the text of the task, each level contains some theoretical part, hints for the students and examples. Developed platform is open-source[1]. Feedback from students has shown their great interest in such kind of tasks, and a high level of motivation and involvement [22].

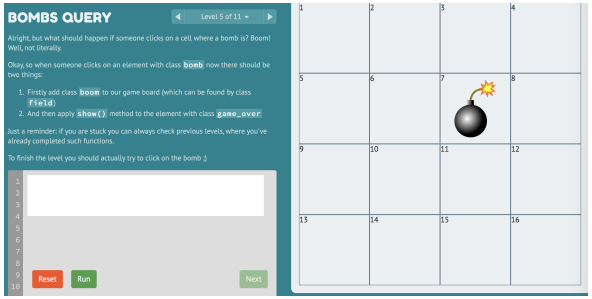

Figure 3: bombsQuery interface example.

Current Surf - enhance conceptual learning with gamification

The *CLR: Current Surf* project is a learning environment with a combination of 3d visualization and game elements (Figure 4). It is used for conceptual learning of electric and electronic circuits at KU Leuven electrical engineering course. Students can choose active learning by interacting with a visualization tool and investigating the influence of altering the circuit components, or learning new material while passing levels in the gamified environment. In the next phase of the project, it is planned to run an assessment of the tool by students' feedback and evaluation. The main reason behind creating two separate parts (with and without gamification) is to have a possibility to compare learning outcomes for both of them. This will help to evaluate the educational domain of introducing game elements to the assignments.

In both cases the game elements have been added on top of the already existing tools, in order to increase students' engagement, and the initial functionality was kept. Hence we consider them to be a *gamification* example.

Dissertation status and next steps

The theoretical part of the dissertation concerning the gamification has been already finished and presented at the Brno University of Technology. I'm also teaching a Web Development course there in order to collaborate with students more and observe their needs and problems during learning new material. Practical implementation is started by developing two different gamification tools, mentioned before. Next phases of the research include: developing a gamified framework with assignments, extending tasks, developing ML algorithm for dynamic difficulty adjustment. Already achieved results and discussions on the conferences show the great interest to the domain, and positive feedback shows the high level of published articles.

Participation in the Doctoral Consortium will help me to shape the project and gain more opinions about questions listed in the "To be discussed" section. Since the idea is to create a generic framework, it is vital to get more in-depth information about educational processes in other institutions and feedback from the research community.

[1] https://github.com/lirael/bombsQuery

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