

## Gamification Elements in STEM Subjects – Lessons Learned from NEWTON Project

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### Abstract

*Gamification – whereby game mechanics are integrated into a non-game experience, such as a learning experience – has a positive effect on learning, increasing students' motivation and engagement. STEM education is not currently taking full advantage of the possibilities offered by the implementation of gamification into science lessons. More worryingly, Europe is facing a shortage of scientists in the future, as students are disengaging from STEM subjects, finding them difficult and irrelevant. Science teaching has not caught up with the millennials, who by nature are digital natives, having grown up in an age of technological advancements and video games. While there are many ways to include gamification into education, the implementations made must be genuinely beneficial, and not only changes for the sake of changes. Here, we present the results of a gamification survey, carried out as part of the NEWTON H2020 Project, and discuss the most useful aspects of gamification mechanisms.*

### 1. Introduction

Games are engaging in a way that few other activities are, and this is particularly true for the current learners, millennials, who are digital natives when it comes to technology. They use technology in their everyday lives and have grown up playing video games. Modern video games also include a great deal of social aspect, and online communication via text, chat and email is considered as normal as talking. However, the way in which STEM (Science, Technology, Engineering and Mathematics) subjects are taught has not kept up with the development of technology. Sciences are still primarily taught in a traditional classroom with a teacher-centered set-up, even though this does not match the skillset the millennials exhibit. They are used to sharing knowledge and receiving instant feedback, while receiving data from several sources at once.

<sup>1</sup> <http://www.newtonproject.eu/>

Technology is their home ground, and these new types of learners require a different approach to education [1]. Pedagogies have not changed but students have. The use of technology such as tablets, laptops and smart phones is becoming more prominent, while video games have conquered an incredibly wide, heterogeneous audience. Gamification – whereby game mechanics are integrated into a non-game experience, such as a learning experience – has a recognized positive effect on user enthusiasm and engagement, particularly amongst millennials [2].

The solution to this mismatch of the skills and requirements of millennials, and the status of STEM education, is the implementation of new pedagogies into the learning experiences. These new pedagogies should include components that embrace and enhance the skills the students possess, while considering the requirements that the future technology-orientated job market will demand. However, before this implementation can be done effectively and in a manner that will truly benefit the modern learners, it is important to understand which components of the gamification mechanisms are the most valued and helpful for both educators and learners. These mechanisms must then be implemented into the new pedagogies while utilizing technology in education.

### 2. NEWTON Project

The NEWTON Project<sup>1</sup>– funded by the Horizon 2020 EU Programme – is aiming to change the way we teach STEM subjects and to provide an engaging student-centered approach to learning. The goal is to connect educators and learners through a large-scale European-wide platform NEWTELP and to offer innovative pedagogies in a virtual environment. Gamification will play a key role in the NEWTELP platform enabling a new interaction concept during learning experiences. The gamification component of this platform was introduced to the wider audience in a workshop in Ireland that focused on gamification in

education [1]. The gamification component is explained in more depth in the next section, followed by details and results of the Gamification Survey, after which conclusions form the final section.

### 3. NEWTON gamification component

The main idea of the NEWTON gamification component is to combine different concepts and aspects deriving from Adaptation and Personalisation, Gamification, Serious Gaming and Socialization to address the entire learning experience, for both learners and educators [3]. The NEWTON Enhanced Gamification Model, which is the theoretical basis of this component and consists of four layers, is described in more detail in [3]. The Gamification Layer aims to create extrinsic motivations in players; it may contain the main elements used in games such as points, badges, levels, virtual coins or money collected by the term of rewards and leaderboards, progress bar and so on. It also contains the set of rules such as the definition or configuration of conditions and actions, which enable the assignment of rewards to the players. The second layer, Serious Games, through the dynamics and aesthetics of the game (i.e. virtual environment, avatar, animated interaction, etc.), create intrinsic motivation and leverage some psychological factors to increase student engagement.

User profiling is fundamental in addressing aspects such as personalisation and adaptation of game contents and the game experience to match specific students' requirements. In the NEWTELP platform, this is implemented into the Profiling and Recommendation Layer. Hence, each student can be characterised by personal data, own interests and preferences, implicit behaviour and individual learning progress. By tracking and storing individual actions, the student's profile will be updated and refined (by using some inference mechanisms to discover new implicit knowledge about him/her) to better inform the system to match personal learning needs, adapt and recommend the single best gamified learning content or pathway, either for the individual or for the team.

Moreover, in line with socialization paradigm, the Social Layer allows students to share their own ideas and ability in order to solve complex problems and stimulate cooperation and team working, by also basing on the use of gamification causing these effects. Finally, in this vision educators still play a fundamental role since they can configure appropriate rules to address more motivation in the learning of specific content, especially those ones considered very difficult by students, to set gamified courses/pathways and they can be active in the social environment to give right suggestions and support to the work of students.

## 4. Gamification survey

### 4.1. Methodology

NEWTON Project partners organized a workshop presented at the 7<sup>th</sup> Irish National Game-Based Learning Conference (iGBL2017), held in Cork, Ireland on June 22<sup>nd</sup>-23<sup>rd</sup> 2017, called "*Gamifying the Learning Experience: Ideas from the NEWTON Project*" [1], which was voted as the best presentation overall. The key goals of the workshop were to explain how the model for gamification connects to the learning experience, and to find out the opinions and thoughts about gamification of the expert audience. In the end of the workshop, the participants, mostly experts from the Education and/or Game-based Learning/Gamification sectors, filled in a survey, which was later distributed to wider gamification expert audiences online.

### 4.2. Results

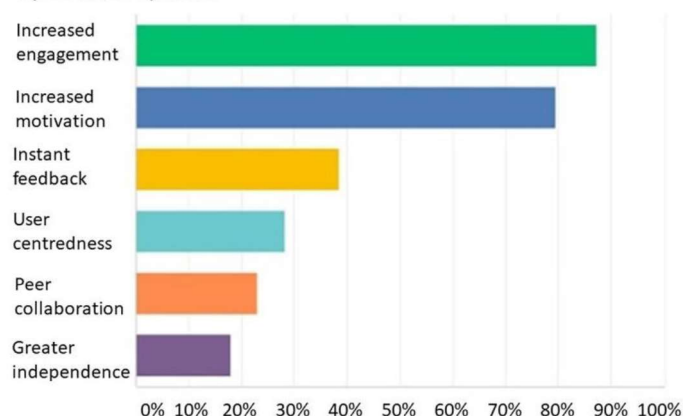
The motivation behind the survey was to find out which gamification elements were thought of as the most useful for educators and learners, and how these were aligned with the principles of the NEWTON-Enhanced Gamification Model. In the survey, 54 participants (42% female, 58% male), 52% of whom were aged between 26 and 35, answered questions on their level of familiarity on gamification, where they saw the value of gamification, especially relating to teaching STEM subjects, and what they considered to be the risks of using gamification in education.

The results, which are discussed in more detail below, show that increased engagement and motivation were considered as the most powerful aspects of gamification (see Figure 1). Clear targets and goals were considered the most useful elements of gamified learning experience (see Figure 2).

Figure 1 shows that the most powerful and useful aspects of gamification and of gamifying a learning experience were increased engagement (87%) and increased motivation (80%). As one of the main drivers behind the NEWTON project is the lack of engagement by students in pursuing STEM subjects, this is encouraging for the implementation of different gamification mechanisms into the platform.

Other studies have shown similar results and proven how gamifying a learning experience does make it more engaging for learners. Hamari [4] carried out a study where students were awarded badges for their work, while the non-gamified control group did not receive badges. Students who received badges reportedly had a significantly higher level of engagement. Similar results were reported by Domínguez et al. [5], with gamification increasing motivation in students. Rocha Seixas et al. [6] found that students who received more rewards and badges also had significantly better average performances in

What do you think are the most powerful and useful aspects of gamification and of gamifying a learning experience? Please choose up to three options.



**Figure 1. The most powerful and useful aspects of gamification and of gamifying a learning experience.**

their coursework and tests. Teachers taking part in this gamification study also noticed how interested and engaged the students were to learn using the online system and reflected on how the awarded badges sometimes did not reflect their expectations for a specific student. This allowed the teachers to look closely at the progress of a specific student and offer more in-depth teaching to an individual. In the NEWTELP platform, the Profiling and Recommendation Layer serves a similar purpose, allowing for both the learner and the educator to track the student's progress and provide insight into the individual learning journey.

Gamifying a learning experience encourages students to communicate with other learners, as the level of activity in forums and projects has been found to increase when gamification has been implemented into the experience [7]. In the NEWTELP platform, the Social Layer encourages students to share their own ideas and allows for cooperation and team work. Other signs of increased motivation and engagement are improved percentage of students passing the coursework, and participation in voluntary activities [8]. In the survey, the third most powerful and useful aspect was instant feedback (40%), which is also something NEWTON virtual labs offer. Furthermore, 89% of the participants agreed that gamification could enhance the learning of STEM subjects.

The participants of the Gamification Survey answered what were, in their opinion, the most useful gamification mechanisms (see Figure 2). For learners to have targets and clear goals were considered as the most useful aspects of gamification. Ideally, goals should be specific, clear, moderately difficult and immediately achievable. Instant feedback was the second most valued gamification mechanism. Immediate rewards are considered more appropriate for learners, especially millennials, than potentially vague long-term benefits [9].

Optimal level of challenge, which is related to personalisation, was considered as the third most useful gamification mechanism. Challenges should be clear, concrete, and actionable learning tasks that increase in complexity as the learner progresses. In the NEWTELP platform, the Profiling and Recommendation Layer enables each student to work at their own level, as the system records their previous work, updates the user profile as the student progresses and tracks individual preferences. The participants of the survey considered team challenges to be important, as these assist students in building their team work and communication skills, while enhancing social engagement loops [9]. Teamwork also gives learners visibility, reputation and recognition, which are important in increasing motivation.

Personalisation was also considered as very useful. Types of personalisation include personalised experiences, adaptive level of difficulty, challenges tailored to the players' level of skill, and scaffolding, i.e. increasing the difficulty as the player's growing skills. Themes, points and prizes (including badges) were also appreciated as gamification mechanisms. Themes as well as storylines have been found to make the learning experience more enjoyable and engaging to learners [10]. Point systems manage the acquisition and spending of points that quantify user performance, while badges reflecting the prestige within players' community are given for special achievements, or for effort of the learner [9]. Avatars and narrative also scored high. Avatars can function as so-called pedagogical agents, who help guide the learning journey [11]. In some learning exercises, students can also create their own avatars, hence adding another touch of personalisation to the learning experience.

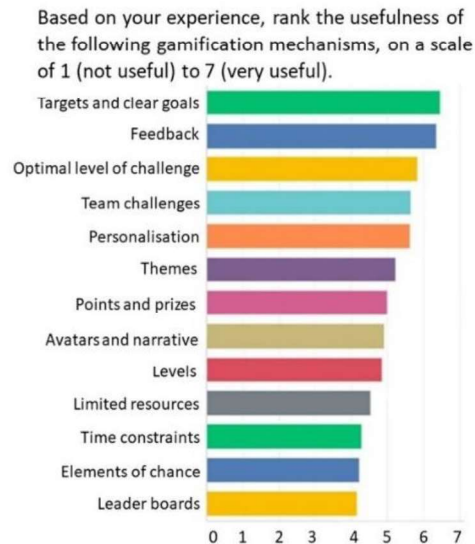


Figure 2. Ranking of the usefulness of gamification mechanisms.

## 5. Conclusion

Research has shown that gamification mechanisms offer ways to make the teaching of STEM subjects more engaging for students, increasing their motivation and bringing relevance to the subjects. Disengagement from science is a serious issue amongst millennials, and by utilizing technology and gamification, we can bring familiarity and increase interest of the learners. The results of this survey emphasize this fact, as they show that the increased engagement and motivation were considered the most powerful and useful aspects gamification has to offer to STEM education. Out of the gamification mechanisms, targets and clear goals, instant feedback and optimal level of challenge were ranked as the most useful ones for learners. In the NEWTON H2020 Project, which aims to motivate and engage students to study STEM subjects, gamification mechanisms play a key role, as we recognize the value and opportunities these provide, and the results of this survey will be used to refine the gamification mechanisms within the system.

## 6. Acknowledgement

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