# How does adaptive gamification impact different types of student motivation over time?

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**ABSTRACT**
The gamification approach is often used in educational settings, with widely varying results on learner motivation. A new trend emerged these last years on adaptive gamification to fit learners' preferences for game mechanics, but little is known on how the adaptation of different game elements impacts different types of learner motivation. In this paper, we propose to investigate in depth the effects of adaptive gamification on a continuum ranging from intrinsic motivation for knowledge to amotivation, by assigned game element. We conducted a field study involving 121 students (aged between 13-15 years old) from secondary schools during four to six weeks, to compare the impact of adapted game elements to randomly assigned ones. This approach allowed us to reveal the following findings: (1) the impact of gamification (either adapted or not) is different when considering each type of motivation, (2) the effects of the use of the gamified environment were only observed after five lessons, (3) the adaptation of the game elements seems to reinforce their effects on learners' motivation, and (4) each game element had specific effects on different types of motivation: while adapted Avatar and Timer had both some positive and negative effects, Progress had mainly detrimental ones.

**KEYWORDS**
Adaptive gamification; Learning environment; Learner motivation; Player profile

## 1. Introduction

Gamification, the use of game elements in non-game situations (Deterding, Dixon, Khaled, & Nacke, 2011), has seen increasing use in education to support knowledge retention (Putz, Hofbauer, & Treiblmaier, 2020), help motivate and engage learners with learning content (Kyewski & Krämer, 2018; Landers, Bauer, & Callan, 2017; Sailer, Hense, Mayr, & Mandl, 2017; Zainuddin, 2018). However, more and more studies show that the gamification approach presents somewhat mixed results, sometimes

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demotivating learners (Ding, Kim, & Orey, 2017; Hanus & Fox, 2015; Klock, Gasparini, Pimenta, & Hamari, 2020). Based on their meta-review on gamification in education Dicheva, Dichev, Agre, and Angelova (2015) argued that more substantial empirical research was needed to investigate the motivational effects of individual game elements for particular types of learners.

Thus, researchers have started to investigate if adapting game elements could have an impact, leading to beneficial effects on learners' motivation (Lavoué, Monterrat, Desmarais, & George, 2019; Monterrat, Lavoué, & George, 2017; Oliveira, Hamari, Joaquim, et al., 2022; Reyssier et al., 2022). These studies point to the fact that the impact of adaptive gamification depends on individual factors, such as the player profile (Hallifax, Serna, Marty, & Lavoué, 2019; Lopez & Tucker, 2018; Monterrat et al., 2017; Orji, Nacke, & Di Marco, 2017) and learners' initial motivation for the learning task (Bennani, Maalel, & Ben Ghezala, 2021; Hallifax, Lavoué, & Serna, 2020; Lavoué et al., 2019). Despite these advances in the field (Oliveira, Hamari, Shi, et al., 2022), the theoretical concept of motivation, which describes the internal and external forces that trigger and maintain goal-directed behaviour, is generally approached from a general perspective, or by differentiating only between intrinsic and extrinsic motivations, when it is a very complex concept that can be examined in multiple ways (Deci & Ryan, 1985; Vallerand, 1997; Vallerand et al., 1992). Research conducted within the well-known framework of the Self-Determination Theory (SDT) (Deci & Ryan, 1985; Vallerand, 1997) shows that a plurality of motivations is possible and not exclusive, and that they depend on the degree to which the individual's fundamental needs for competence, relatedness and autonomy are satisfied.

In this paper, we analyse the impact of adaptive gamification on learners' motivation using a fine-grained approach based on the SDT (Deci & Ryan, 1985; Vallerand, 1997). We distinguish three types of intrinsic motivation (i.e. engaging in an activity for the pleasure inherent in that activity), three types of extrinsic motivation (i.e. doing an activity for the purpose of obtaining an external goal) and amotivation (i.e. the absence of motivation). Several game elements are adapted to learners' profile, which considers both their player preferences and initial motivations for the learning activity. We present a large-scale field study in real-world classroom conditions, involving 121 students (aged between 13-15 years old) in six classes, from *European (masked for peer review)* secondary schools. The students completed eight maths lessons of approximately 40 minutes on a gamified learning environment specifically developed for this research project. We tracked learners' motivation by using the AMS motivational scale (Vallerand et al., 1992) at three distinct points during the experiment (before using the system, after 5 sessions, and at the end), and compare the variations between two experimental groups: learners who used a game element adapted to their profile, and those who used a randomly assigned game element. We used a previously validated method to assign adapted game elements to learners based on their profile (Hallifax et al., 2020). We also analyse the motivational variations for each individual game element, whether it was used in an adapted setting or not.

Our findings contribute to the gamification and learning technologies research communities in two ways: (1) by showing in a real-world setting how adapting gamification to individual learners using their player preferences and initial motivations for learning can have an influence on their motivation; (2) by providing greater insights into how adaptive gamification can affect specific types of learner motivation over time, depending on the game element integrated into the learning environment.

## 2. Related work

### *2.1. Theoretical foundations: Self-Determination Theory*

The well-established Self-Determination Theory (SDT) (Deci & Ryan, 2013) is the most frequently used psychological theory in gamification research (Seaborn & Fels, 2015; Zainuddin, Chu, Shujahat, & Perera, 2020). Most design approaches rely on this theory to implement game elements that intend to satisfy three innate, universal psychological needs (Deterding, 2015). *Competence* is defined as the need to gain mastery of tasks and learn different skills, *Autonomy* as the need to feel in control of one's own behaviours and goals and *Relatedness* as the need to experience a sense of belonging and attachment to other people. The satisfaction of these three needs depends on the way extrinsic contingencies are more or less internalised in the Self (Ryan, Deci, & Grolnick, 1995), determining if people are mostly intrinsically or extrinsically motivated. Over the years, researchers have thus come to identify two types of motivation, organised on a continuum ranging from non-self-determined to self-determined behaviours. Intrinsic motivation (IM) refers to engaging in an activity for the pleasure inherent in the activity, while Extrinsic motivation (EM) is concerned with expected benefits from a situation, in order to receive something positive or to avoid something negative once the activity is terminated (Deci & Ryan, 1985).

Deci and Ryan (1985) proposed to distinguish four types of extrinsic motivation according to the degree of regulation of the learner, ranging from the less to the more self-determined: *external regulation* (motivation is exclusively external and regulated by compliance, conformity, external rewards and punishments), *introjected regulation* (behaviours performed to avoid shame or self-esteem, for which contingencies are partially external), *identified regulation* (behaviours issued by choice in order to achieve specific objectives, the activity is judged as important for the individual), and *integrated regulation* (the most integrated form generating totally self-determined and self-regulating behaviours, in accordance with values, needs or personality, but only adults are concerned with it). Finally, their consider *Amotivation* as non self-determined, corresponding to an absence of motivation, either intrinsic or extrinsic.

Expanding this line of research, Vallerand and his colleagues (Vallerand, 1997; Vallerand et al., 1992) proposed the Hierarchical Model of Intrinsic and Extrinsic Motivation to provide a framework for organizing and understanding the basic mechanisms underlying intrinsic and extrinsic motivational processes. They suggest that intrinsic motivation (IM) could be subsumed into three major types. *IM to know* relates to engaging in an activity for the pleasure and satisfaction of learning, exploring and trying to understand something new. *IM toward accomplishment* refers to engaging in an activity for the pleasure experienced when attempting task mastery. *IM for stimulation* is operative when one engages in an activity in order to experience pleasant sensations, excitement, or aesthetic enjoyment.

Relying on the SDT theory, feeling competent and/or autonomous in a learning situation would influence the self-determination of learners and be positively correlated with their performances (Deci, Koestner, & Ryan, 2001). The findings of a systematic review of studies on the impact of gamification on learning and instruction conducted by Zainuddin et al. (2020) also empirically show that the values of engagement and motivation are always positively correlated with a student's academic performance. These authors state that both intrinsic and extrinsic motivation play crucial roles in promoting students' learning engagement. The question of the impact of the gamification approach on learners' motivation thus seems fundamental in the educational domain.

### 2.2. Gamification in education: effects on learner motivation

Several studies have been conducted since 2011, as shown in several recent meta-analysis (Sailer & Homner, 2020; Zainuddin et al., 2020). Some studies evaluate the impact of a single game element. For example, Filsecker and Hickey (2014) tested the effects of external rewards on motivation and engagement in fifth graders. They found that including these rewards avoided a decrease in their intrinsic motivation and increased learner conceptual understanding of the studied topic. Kyewski and Krämer (2018) obtained more nuanced results when evaluating the impact of badges integrated into an online learning environment used over 5 weeks in three different conditions (no badges, badges visible to peers, badges visible only to students themselves). Regardless of condition, the intrinsic motivation of students decreased over time.

Other studies consider several game elements in a same gamified learning system. For example, in a study on how gamification affects online learning discussion, Ding et al. (2017) showed that learners were more interested in the game elements that were directly linked to their grades. Also, Denny, McDonald, Empson, Kelly, and Petersen (2018) tested the effect of scores and badges on learner behaviour and found that only the latest had an effect on how participants behaved, increasing the number of self assessments made. They also found that this directly resulted in better examination performance for those participants. Rodrigues et al. (2021) tested a gamified programming learning course with 19 students and showed that gamification strongly affected learner intrinsic motivation (which in turn greatly predicted learner performance). They found that the more learners were familiar with the learning content (computer programming), the more they gained in intrinsic motivation. Bouchrika, Harrati, Wanick, and Wills (2019) also found that the impact of gamification on students' engagement with the e-learning gamified system was considerably positive due to the large volume of published content and earned points.

Several studies compare the impact of gamified and non-gamified learning environments. For instance, Zainuddin (2018) tested two versions of a flipped class setting: one with gamification (points, badges and leaderboards) and one without. They found that learners provided with the gamified environment had increased levels of perceived competence, autonomy, and relatedness, better performance, and were able to achieve better results during the tests. On the contrary, Monterrat, Desmarais, Lavoué, and George (2015) showed that learners who were free to use a non-gamified learning environment had a higher level of intrinsic motivation after the experimentation, compared to learners using a gamified environment. Similarly, Hanus and Fox (2015) observed that students involved in a course gamified with badges and a leaderboard showed less motivation, satisfaction, and empowerment over time than those in the non-gamified class. Ferriz-Valero, Østerlie, García Martínez, and García-Jaén (2020) tested a gamified approach to a university training course. They found that whilst gamification had a positive effect on academic performance and on external regulation, they did not see an effect on intrinsic motivation for physical education.

As a conclusion, we can first note that most of the studies analyse intrinsic and/or extrinsic motivation as a whole, and do not distinguish different types of motivation in finer grains, on a continuum from amotivation to intrinsic motivation (see section 2.1). To date, only two studies distinguish between the different types of motivation. Buckley and Doyle (2014) show that gamification is particularly effective for students who are intrinsically motivated, particularly either by a motivation to know or a motivation towards stimulation. van Roy and Zaman (2018) analysed the impact of gamification on learners during a 15-week experiment and showed that all types of motivation changed over time: decreased and then increased at the end of the course (except for amotivation and controlled motivation), without returning to their initial level. There is therefore a need for a better understanding of the effect of gamification on the different types of motivation, in order to lead learners towards self-determined learning behaviours. This is the main objective of the present study.

Second, we observe rather mixed, even contradictory, results when comparing studies, as recently highlighted by Sailer and Homner (2020) in their meta-analysis. Whereas the positive effects of gamification on cognitive learning outcomes can be interpreted as stable, results on motivational and behavioral learning outcomes have been shown to be less stable. This could be explained by the use in all the reviewed studies of what is commonly referred to a "one size fits all" approach, i.e. providing learners with the same gamified experience. This, however, could be somewhat ineffective, as recent research shows that learners have different expectations, preferences, and needs from the learning experience (Bennani, Maalel, & Ghezala, 2020; Hassan, Habiba, Majeed, & Shoaib, 2021). This finding is echoed by van Roy and Zaman (2018, p.293) who concluded that "the effects are highly personal and can differ widely between different learners". Santos et al. (2021) also show that certain game elements were more suited to certain player profiles, hence the need to adapt to the learner's player profile. Our research is thus focused on a new trend named adaptive gamification, which aims to adapt game elements to learners' characteristics, preferences and motivations.

### *2.3. Adapting gamification in education: methods and effects*

In recent literature reviews, Hallifax, Serna, Marty, and Lavoué (2019) and Oliveira, Hamari, Shi, et al. (2022) looked at the information used to adapt gamified systems to learners in educational settings. The adaptation process is mainly based on learner player profile (preferences and reasons why people play games), although some systems use more learning specific data, such as learning styles, or learning motivations.

Some studies have shown positive results when adapting. For example, Roosta, Taghiyareh, and Mosharraf (2016) presented learners with different game elements based on their motivation type (Mastery approach vs. avoidance, Performance approach vs. avoidance). After using an online learning tool for one month, learners who had game elements suited to their motivation type showed significant increases in motivation compared to learners who had randomly assigned game elements. Hassan et al. (2021) also showed that learners who used game elements adapted to their learning style (Felder, Silverman, et al., 1988) reported higher motivation rates than those who used random game elements. In a study conducted by Mora, Tondello, Nacke, and Arnedo-Moreno (2018), university learners were sorted into different groups based on their Hexad player profile (Marczewski, 2015) and used a learning tool over a period of 14 weeks, each group receiving different game elements. The authors report a general positive impact from their adaptation process, with an increase in behavioural and emotional engagement in learners. Finally, Rodrigues et al. (2021) showed that the students using a personalised design were more motivated than those using the one-size-fits-all approach regarding intrinsic motivation and identified regulation.

However, some other studies have shown somewhat mixed results of the adaptation process. Monterrat et al. (2017) showed that middle-school learners with counter-adapted game elements found their game elements to be more fun and useful than learners with adapted or randomly assigned elements. The authors performed a similar study reported in (Lavoué et al., 2019), with adults who used the learning tool voluntarily. Before using the learning environment, learners were given a game element that either corresponded to their highest scoring player type, or their lowest scoring player type (thus creating adapted and counter-adapted experimental groups). They found differences only for the most engaged learners with adapted game elements who spent more time in the learning environment than those with counter-adapted ones and showed less amotivation. In another study, Paiva, Bittencourt, Tenório, Jaques, and Isotani (2016) analysed the usage data during the month after the introduction of tailored goals in their learning tool used for learning mathematics. They found that while the social and collaborative goals were effective in increasing the number of related actions, this effect was not observed with individual learning goals. The study reported in (Rodrigues et al., 2021) can also be considered as having mixed results, as gamification had a negative effect on learners who were less familiar with programming.

To sum up, we observe that, as with one size fits all gamification, tailored gamification in education still has somewhat mixed results. There is no consensus on the effect of gamification and this effect may vary depending on the type of game elements used and on the context it is deployed (Hallifax, Serna, Marty, Lavoué, & Lavoué, 2019). We believe that this line of research is still in its infancy and that there is a need to investigate more deeply which learner characteristics should be considered in the adaptation process depending on the game element used. We agree with Bennani et al. (2021) that it is crucial to take into account different changing aspects such as learners' motivations, and not only player types, to understand which mechanisms and dynamics can enhance their motivation in specific contexts.

## 3. Research questions

Our study focuses on the impact of adaptive gamification on learners' motivation considering the seven types of motivation identified in the SDT (Ryan et al., 1995), as well as their evolution over time, to take into account the complex and evolving nature of motivation. We perform fine grain analyses by game element suggested by an adaptation algorithm we developed (see section 5.4), as we believe that learners' motivation will depend on their perception of the situation and the environment, in our case the use of a gamified learning environment dedicated to learn maths (described in next section).

In this paper, we propose to investigate the following research questions:

- **RQ1** How does adapting gamification to learners' initial motivation and player profile affect the different types of motivation?
- **RQ2** How do these effects evolve over time?
- **RQ3** How do individual adapted game elements affect the different types of learner motivation?

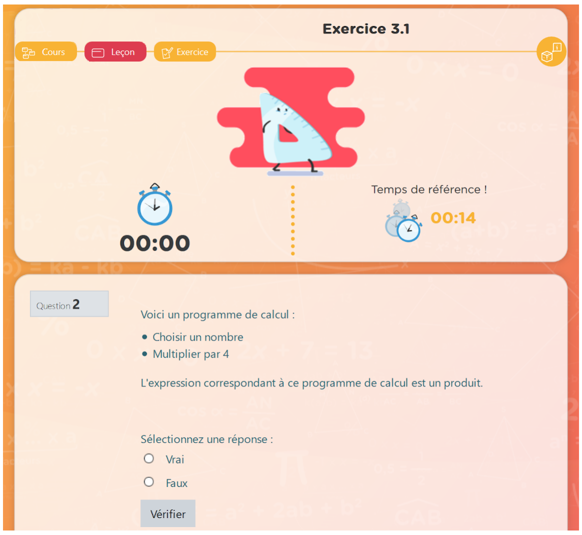


**Figure 1.** A screenshot of the LudiMoodle learning platform showing the Timer game element and a question in a quiz.

## 4. Learning environment

Learners used the gamified learning platform LudiMoodle, a modified version of the Moodle Learning Management System (see figure 1). This platform was developed within the scope of the LudiMoodle project which brings together researchers in computer science and in educational sciences, pedagogical designers, four middle schools and a Moodle development company.

### *4.1. Learning content*

All of the learning content was created by the participating teachers so that it would be as close as possible to their teaching practices. The teachers designed seven lessons, composed of several quizzes (4 to 10) that covered the topic of secondary school level basic algebra (in particular literal arithmetic). The quizzes were designed as training exercises since teachers had observed that learners generally found these exercises to be boring or too repetitive, and they wanted to make these exercises more engaging for learners. Within a lesson, to successfully complete a quiz and progress to the next one, learners had to answer at least 70% of all questions correctly otherwise they had to start the quiz again.

### *4.2. Game elements*

The gamified learning platform was developed according to an iterative design process with participatory design sessions with the different stakeholders of the project (teachers, game designers, educational engineers, the company in charge of the development), using the design method and design space presented in (Hallifax, Serna, Marty, & Lavoué, 2018). This platform integrates six game elements: points and badges (for the Reward dynamic), progress bar and ranking (corresponding to leaderboards and competition) (for the Progress dynamic), and avatar (for the Self representation dynamic). In addition, teachers selected timer (for Time pressure dynamic) for its suitability for the quiz format, although this element has been little studied in the literature (Butler, 2014; Monterrat et al., 2015). Each of the six game elements corresponds to at least one of the different Hexad player types (Marczewski, 2015) and cover the different kinds of learners' motivation as defined in the Self Determination Theory (SDT) (Deci & Ryan, 1985, 2000a). In fact, we rely on this theory, and a derived questionnaire (Vallerand et al., 1992), to identify learners' initial motivation as a characteristic of their profile (see section 5.3).

We present in this section only the three game elements that were proposed to learners through the adaptation process described in section 5.4[1]: progress bar, avatar and timer. Note that each of the game elements had a small information popup that opens automatically at the start of each lesson to inform and remind learners how it works. Learners could access this popup at anytime via a button on the interface.

**Progress bar**. Learners were shown their progress in the quizzes by way of a rocket ship that travelled from earth to various planets. Each correct answer would charge a "boost" meter that, when filled, would propel the rocket further. When learners achieved a full 100% of correct answers for a lesson, they would arrive at the planet.

**Avatar**. The Avatar game element showed a goblin-like character that learners could personalise with various clothes and equipment. As the learners progressed in a lesson they could unlock a different set of objects to use (e.g. medieval, fairy tale, pirates). The Avatar could be personalised via an inventory menu displayed near the top of the game element. In general, when learners achieved the required 70% in each quiz in a lesson, they could unlock 1 or 2 objects.

**Timer**. This game element showed a Timer for each quiz. Each of the questions was timed and recorded. Learners were shown the average time taken to answer to previous questions and each time they beat this "reference time" a small maths related character ran faster and faster. Learners were thus encouraged to make their character as fast as possible by answering quickly. They were only rewarded for correct answers, an incorrect answer would not affect the reference time or the animated character.

## 5. Study design

### *5.1. Procedure*

Before the use of the learning environment, we first asked learners to fill out two questionnaires to establish their player profile and their initial motivation for doing math exercises (see section 5.3). Learners were then sorted into one of two experimental conditions. In the control group, learners were randomly assigned a game element. In the experimental group, learners were assigned a game element adapted to their profile 5.4). Once a game element assigned to learners, they used it for the entire experiment duration. In total, learners used the platform during eight lessons dedicated to the topic.

Then learners followed the lessons between once and twice a week during four to six weeks. They accessed the quizzes individually using a tablet device. Each lesson was carried out in the same way: teachers gave a short introduction to the lesson's topic (10-15 minutes depending on the complexity). Learners then logged into the gamified learning platform to solve quizzes related to that lesson (25-30 minutes).

After five lessons, during a formative assessment session, learners completed the motivation questionnaire a second time. After the final lesson, learners filled out the

[1]Readers can refer to (Reyssier et al., 2022) to have more details on all six game elements.

motivation questionnaire a third time. This allowed us to track learners' motivation more accurately and to identify the variations in the first period (between the first and the fifth lessons) and in the second period (between the sixth and the eighth lessons) of the experiment.

### *5.2. Participants*

154 learners in six secondary schools classes in France participated in our experiment. We considered only data from learners who have 1) answered the three questionnaires; 2) done all the lessons. Those that did not satisfy these two conditions were removed from the analysis to ensure data consistency. Data of 121 learners could be processed (58 self reported as female, 63 as male), 83 learners were in the adapted condition and 38 in the non adapted condition.

### *5.3. Profile questionnaires*

Learners filled out both the Hexad (Marczewski, 2015)[2] and AMS (Vallerand et al., 1992) questionnaires to determine their profile (player and initial motivation for mathematics). The HEXAD typology is grounded on the SDT theory (Deci & Ryan, 2000b), which defines the three core intrinsic motivators as competence/mastery, autonomy, and relatedness. The motivation scale proposed by Vallerand et al. (1992) relies on the same theoretical framework and was especially designed for Education. It evaluates the seven types of motivation described in details in section 2.1, except for integrated regulation. Each of these types identifies the reasons why someone would perform an educational activity, in our case learning maths. We provide the detail of the questionnaires in appendix.

### *5.4. Adaptation algorithm*

As introduced in section 4.2, the platform allowed us to assign a specific game element to each learner during the initialisation step. The adaptation algorithm relies on the results of a previous experiment conducted with the same gamified learning environment and 258 same aged learners in secondary schools in France. In this first experiment, we analyzed the effect of game elements on learners' motivation who used the environment in class during ten lessons (Reyssier et al., 2022). We randomly assigned one game element to each learner, to be able to identify the impact of each game element separately. We performed statistical analyses using the partial least squares path modeling (PLS-PM) method (Hair, Hult, Ringle, & Sarstedt, 2021), which estimates complex cause-effect relationships in path models with latent variables. The results show different effects on learners, in particular significant influences of their initial level of motivation and their player types on the variation in motivation during the study. We showed that these influences vary according to the game element they used.

The dataset collected during this first experiment was then used to compare three types of adaptation of game elements to learners' profile: (1) an adaptation based on learners' player profile (Hexad), (2) an adaptation based on their initial motivation for the discipline (AMS), and (3) an adaptation based on a compromise between both

[2]we used the French version proposed at `https://hcigames.com/wp-content/uploads/2019/11/Hexad-Survey-and-Instructions` $_F R.pd$

profiles. We showed that tailoring to both player and motivation profiles can improve intrinsic motivation, and decrease amotivation, compared to a single adaptation only based on either the Hexad profile or the initial motivation for mathematics separately (Hallifax et al., 2020). This result is also supported by the recent literature review on tailored gamification (Klock et al., 2020), which recommends that adaptation should not be based solely on one aspect of the users' characteristics.

Therefore, to determine which game elements to assign to learners in this new experiment, we used the compromise adaptation algorithm we proposed, which considers both the game element that would be recommended for the player profile and the game element relevant to the initial motivation of learners. Figure 2 presents an overview and example of how this adaptation works (the algorithm is detailed in the appendix). For the two single profiles (Hexad and AMS), we relied on our dataset to identify the influences of the profile values on the variations of motivations for each particular game element. These influences were calculated using the PLS-PM method described above, giving us a set of 6 influence matrices for each profile (one for each game element). By combining all six matrices, we obtained an "influence matrix" for each of the profiles (Hexad and initial motivation), which coded the positive or negative influences of each dimension of the profile according to each game element.

We then multiplied the individual learner profiles with these influence matrices, which gave us two "affinity" vectors for each learner (one based on each profile). These affinity vectors showed how well suited each game element should be for a given learner. Finally, the compromise algorithm select the most appropriate game element based on the affinity vectors. It first checks for positive affinity overlaps between the two affinity vectors. If any game elements have positive affinities in both vectors, it combines the ranks of these game elements, selecting the lowest ranked game element. If there is no game element in this overlap, it then combines the rankings of the affinity vectors for all game elements (again selecting the lowest ranked). If at any point there is a tie for lowest ranked, it adds the affinities from both vectors and selects the game element with the highest affinity.

For example, considering a learner with the Hexad profile (Pl:0; Ac:-8; So:2; FS:0; Di:6; Ph:7) and the following initial motivation for mathematics (Mico:9; Miac:11; Mist:10; ExtReg:12; IdReg:7; IntReg:8; Amot:8). The algorithm will first calculate the affinity vectors for each profile, giving the following Hexad affinity vector ('Avatar': .385, 'Badges': .0364, 'Progress': -.241, 'Leaderboard': -.920, 'Points': -.577, 'Timer': .225) and the following Motivation affinity vector: ('Avatar':-6.188; 'Badges':-42.22; 'Progress':2.871; 'Leaderboard':-0.899; 'Points':-50.899; 'Timer':-23.807). The algorithm then check for positive overlap in these vectors (Avatar and Badges for Hexad and Progress for initial motivation). As the overlap is zero, we combine the rankings for all game elements resulting in ('Avatar':4; 'Progress':5; 'Timer':6; 'Leaderboard':8; 'Badges':8, 'Points':11) and would therefore be recommended the Avatar game element (see figure 2).

Upon reviewing the final data from the algorithm, we realised that only three of the six game elements were assigned to learners: Avatar, Progress, and Timer. This was due to the fact that as presented in (Reyssier et al., 2022), the other three (Badges, Leaderboard, and Points) have a majority of neutral (for Badges) or negative influences on the different types of learner motivation. This means that these game elements would have only been attributed to very specific profiles, that were simply not present amongst the learners who participated to the present study. This result is in line with other studies that reported that badges did not successfully increase intrinsic motivation (Kyewski & Krämer, 2018) and that the use of points, badges, levels and

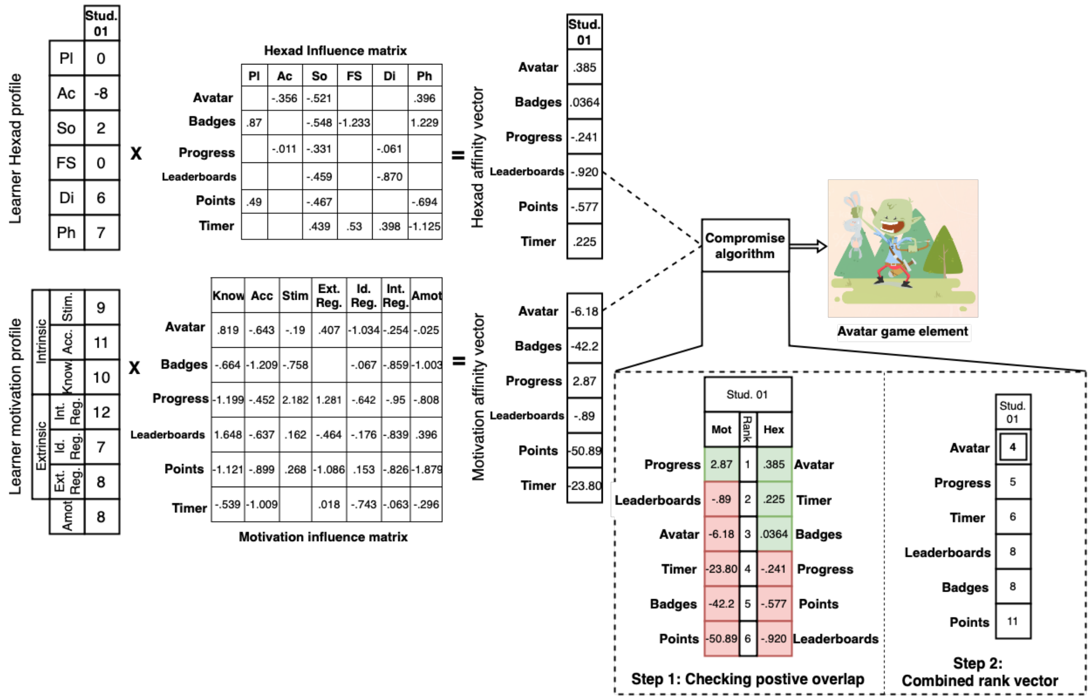


**Figure 2.** Learner adaptation process. Both the learners' Hexad and initial motivation profiles are used to adapt (the compromise algorithm is fully described in appendix). In this example, we show how Student 01's profiles are used to recommend the Avatar game element: both the Hexad and Motivation influence matrices are obtained by adding the individual partial least squares result matrices for each game element. There is no positive overlap in the affinity vectors, so we combine the rankings for each game element.

**Table 1.** Number of students per condition, per game element.Number of students per condition, per game element.

| Condition | Avatar | Timer | Progress |
|---|---|---|---|
| Non-adapted | 12 | 11 | 15 |
| Adapted | 14 | 51 | 18 |

leaderboards did not significantly increase students' competence, need for satisfaction and intrinsic motivation (Ding et al., 2017; Mekler, Brühlmann, Tuch, & Opwis, 2017).

We report in Table 1 the number of participants who were assigned one of the available game elements. The students in the control group who received the correct element (i.e. the element that would be assigned by the algorithm) are counted towards the experimental group.

## 6. Results

### *6.1. General effects of adaptation on learner motivation*

When looking at the results in Table 2, we first observe that the level of motivation at the beginning of the experiment is rather the same for the two groups in each type of motivation (no significant differences are observed). The level of motivation at the end of the course can be obtained by summing the initial motivation and the variation of motivation.

**Table 2.** Mean variations of the different motivation types between the pre and post-tests. The results are presented for the adapted condition (column **Adapted**) and the non adapted condition (column **NonA**). The mean value of the initial motivation for each condition is presented in column **Init. Mot**. The cells are colour coded based on the results of the Wilcoxon test: values in grey are not significant (p>.050), values highlighted in light grey are significant (p<.050), in dark grey are highly significant (p<.010), and black are extremely significant (p<.001).

| | | Adapted | | Non Adapted | |
|---|---|---|---|---|---|
| | | **Init. Mot.** | **Variation** | **Init. Mot.** | **Variation** |
| | Know. | 14.02 | 0.52 | 14.16 | 0.13 |
| | Accom. | 15.52 | -5.8 | 15.03 | -5.92 |
| Intrinsic | Stim. | 11.98 | 2.21 | 12.18 | 1.32 |
| | Id. Reg. | 15.35 | -2.34 | 15.79 | -1.26 |
| | Int. Reg. | 14.12 | 0.68 | 13.68 | 0.64 |
| Extrinsic | Ext. Reg. | 16.23 | -2.93 | 15.61 | -1.74 |
| Amotivation | Amot. | 7.33 | 5.59 | 7.34 | 5.84 |

To answer **RQ1**, we performed Wilcoxon rank sum tests to compare the variations of each type of motivation between the group of learners who used an adapted game element and those who used a randomly assigned one (intra-group comparison). We also performed Kruskal-Wallis tests to compare each motivation variation between the two groups but we observe no statistically significant differences (inter-group comparison).

Considering intra-group comparisons, whether the elements are adapted or not, we note two trends in the effects of the gamified environment on learners' motivation (see Table 2). On the one hand, it significantly increased learners' *IM for stimulation* (Adapted: ΔMean=2.21,W=3.802, p<.001; Non Adapted: ΔMean=1.32, W=2.111, p<.050), and in the same time their *amotivation* (Adapted: ΔMean=5.59, W=5.802, p<.001; Non Adapted:ΔMean=5.84, W=4.213, p<.001). This means that at the end of the experiment learners were feeling more fun in doing maths, but at the same time some of them were less willing to do this activity.

On the other hand, learners significantly lost *IM for accomplishment* (Adapted: ΔMean=-5.8, W=-5.557, p<.001; Non Adapted: ΔMean=-5.92, W=-4.468, p<.001), *identified regulation* (Adapted: ΔMean=-2.34, W=-4.693, p<.001; Non Adapted: ΔMean=-1.26, W=-2.009, p<.050) and *external regulation* (Adapted: ΔMean=-2.93, W=-5.171, p<.001; Non Adapted: ΔMean=-1,74, W=-2.322, p<.050). This means that learners were less motivated to accomplish the activity, had less precise objectives and were less concerned about grades and other rewards than when they started using the gamified environment.

Regarding inter-group comparison, even if no significant differences were observed, it is important to note that the effects seem to be more pronounced for the adapted condition when compared to the non adapted condition for the *IM for stimulation*, the *identified regulation* and the *external regulation* (see Table 2). For instance, for the learners in the adapted condition the change in *IM for stimulation* is significant at the 0.001 level whereas it is only significant at the 0.05 level for learners in the non-adapted condition.

### *6.2. Effects of the adaptation of game elements over time*

To answer **RQ2** we split the variation of learner motivation into two periods: the first variation (difference between pre and middle tests) and the second variation (difference

**Table 3.** Mean variations in the **First** (*Mid test-Pretest*) and **Second** parts of the experiment (*Posttest-Mid test*). The results are presented for the adapted condition (column **Adapted**) and the non adapted condition (column **NonA**). The cells are coloured following the same scheme as in table 2.

| | | **First part** | | **Second part** | |
|---|---|---|---|---|---|
| | | **Adapted** | **NonA** | **Adapted** | **NonA** |
| | Know. | -0.18 | -0.63 | 0.7 | 0.76 |
| | Accom. | -0.38 | -0.05 | -5.42 | -5.97 |
| Intrinsic | Stim. | -0.03 | -0.02 | 2.24 | 1.34 |
| | Id. Reg. | -0.17 | -0.66 | -2.17 | -1.19 |
| | Int. Reg. | -0.6 | 0 | 0.87 | 0.64 |
| Extrinsic | Ext. Reg. | -0.21 | 0.07 | -2.72 | -1.81 |
| Amotivation | Amot. | 0.3 | -0.23 | 5.29 | 6.07 |

between middle and post tests), as illustrated in Table 3.

Regarding intra-group comparison, during the first period we can see that no type of motivation significantly varied neither in the condition with adapted game elements nor in the condition with elements that were randomly assigned, except a small decrease in *identified regulation* in the non adapted condition (ΔMean=-0.66, W=-2.300, p<.050).

During the second period, we observe significant differences for each condition with the same trends as for the global variations. On the one hand, the results show positive effects with a significant increase in *IM for stimulation* in the two groups (Adapted: ΔMean=2.24, W=3.907, p<.001; Non adapted: ΔMean=1.34, W=2.032, p<.050), and a significant increase in *IM for knowledge* (ΔMean=0.76, W=2.170, p<.050) and in *introjected regulation* (ΔMean=0.87, W=2.251, p>.050) only for the adapted condition. It is noteworthy that we did not observe the latest result in the global variation.

On the other hand, we observe a significant decrease in both groups in *IM for accomplishment* (Adapted: ΔMean=-5.42, W=-5.506, p<.001; Non adapted: ΔMean=-5.97, W=-4.151, p<.001) and *external regulation* (Adapted: ΔMean=-2.72, W=-4.736, p<.001; Non adapted: ΔMean=-1,81, W=-3.898, p<.050). We also observe a significant increase of *amotivation* (Adapted: ΔMean=5.29, W=5.515, p<.001; Non Adapted: ΔMean=6.07, W=-4.138, p<.001). We also observe in the adapted condition a decrease in *identified regulation* (ΔMean=-2.17, W=-4.597, p<.001).

Regarding inter-group comparisons, as for the global variation we do not observe significant differences, except for the *identified regulation* with a decrease that is significantly more pronounced in the adapted condition than in the non adapted one (H=-2.143, p=0.032) (3). We note that the effects seem to be more pronounced for the adapted condition when compared to the non adapted condition for the *IM for knowledge* and *external regulation.* On the contrary, the decrease in *IM for accomplishment* seems more pronounced in the non adapted condition.

### *6.3. Effects of adaptation on learner motivation for each game element*

To answer **RQ3**, Table 4 shows the results of the variation of the different types of motivation in the two conditions for each game element.

The use of the **Avatar**, when adapted, has a significant positive effect on *IM for knowledge* (ΔMean=1, W=2.414, p<.050) and *IM for stimulation* (ΔMean=4.72, W=2.789, p<.010). However, it also has a significant negative effect with a decrease in *IM for accomplishment* (ΔMean=-12.83, W=-3.246, p<.001), *identified regulation* (ΔMean=-1.94, W=-2.190, p<.050) and *external regulation* (ΔMean=-2.43, W=-2.094, p<.050), and an increase in learners' *amotivation* (ΔMean=11.86, W=3.245, p<.001). When not adapted, Avatar only decreased significantly learners' *IM for accomplishment* (ΔMean=-6.59, W=-2.805, p<.010) and increased their *amotivation* (ΔMean=6.91, W=2.714, p<.010).

**Table 4.** Mean variations in motivation for the different game elements in the adapted and non adapted (NonA) conditions. The cells are coloured following the same scheme as in table 2.

| | | Avatar | | Progress | | Timer | |
|---|---|---|---|---|---|---|---|
| | | Adapted | NonA | Adapted | NonA | Adapted | NonA |
| | Know. | 1 | -0.25 | 0.2 | -0.07 | 1.06 | 0.82 |
| | Accom. | -12.83 | -6.59 | -6.26 | -4.73 | 1.05 | -6.82 |
| Intrinsic | Stim. | 4.72 | -0.67 | 1 | 3.2 | 3.72 | 0.91 |
| | Id. Reg. | -1.94 | 1.25 | -2.85 | -2.4 | -1.22 | -2.46 |
| | Int. Reg. | 1.5 | -1 | -0.65 | 1.06 | 0.11 | 1.81 |
| Extrinsic | Ext. Reg. | -2.43 | -0.5 | -2.47 | -2.8 | -4.61 | -1.63 |
| Amotivation | Amot. | 11.86 | 6.91 | 5.85 | 5 | 0 | 5.82 |

**Progress**, in both conditions, had negative effects with a decrease in *IM for accomplishment* (Adapted: ΔMean=-6.26, W=-4.929, p<.001; Non adapted: ΔMean=-4.73, W=-2.639, p<.010), *identified regulation* (Adapted: ΔMean=-2.85, W=-4.399, p<.001; Non adapted: ΔMean=-2.4, W=-2.313, p<.050), and an increase in *amotivation* (Adapted: ΔMean=5.85, W=5.024, p<.001; Non adapted: ΔMean=5, W=2.802, p<.050). In addition, it decreased *external regulation* in the adapted condition (ΔMean=-2.47, W=-3.885, p<.001), whereas we observe a significant positive increase in *IM for stimulation* in the non-adapted condition (ΔMean=3.2, W=2.595, p<.001).

Regarding the **Timer** game element, we observe an increase in *IM for stimulation* (ΔMean=3.72, W=2.409, p<.050), and a decrease in *external regulation* (ΔMean=-4.61, W=-2.847, p<.010) when it is adapted to learners' profile. When not adapted, the Timer had only negative effects with a decrease in *IM for accomplishment* (ΔMean=-6.82, W=-2.299, p<.010) and in *identified regulation* (ΔMean=-2.46, W=-2.316, p<.050), and an increase in *amotivation* (ΔMean=5.82, W=2.041, p<.050).

We conducted inter-group comparisons between the global variations in learners' motivation, depending on the game element received, using a Kruskal-Wallis Test (see Table 5). We note significant differences between the two conditions with the

**Table 5.** Kruskal Wallis results comparing between adapted and non adapted conditions for each game element for each type of motivation. The cells are coloured following the same scheme as in table 2. The values in *italics* are slightly significant (p=.082)

| Variations | | | Avatar | Progress | Timer |
|---|---|---|---|---|---|
| Global | 3*Intr. | Know. | 3.883 | 0.731 | 0.322 |
| | | Accom. | 5.061 | 0.274 | 6.247 |
| | | Stim. | 5.293 | *3.019* | 1.546 |
| | 3*Extr. | Id. Reg. | 4.845 | 0.148 | 0.773 |
| | | Int. Reg. | 2.483 | 0.109 | 1.28 |
| | | Ext. Reg. | 0.968 | 0.015 | 2.092 |
| | Amot. | Amot. | 4.181 | 0.24 | 4.285 |

**Avatar** game element in the global variation of most types of motivation, except for *introjected regulation* and *identified regulation*. Regarding the **Progress** game element, we note a slightly significant difference in the *IM for stimulation* (H=3.019, p=.082). Finally, with the **Timer** game element, we observe significant differences in learners' *IM for accomplishment* (H=6.247, p<.050) and *amotivation* (H=4.285, p<.050).

## 7. Discussion

### *7.1. General effects of adaptive gamification*

The first major finding of our study is that adaptive gamification had no significant effect on the global variations of motivation compared to randomly assigned game elements. We observe significant effects on several types of motivation within each condition, following the same trends, although adaptation seems to reinforce these effects. This result echoes those of the study conducted by Oliveira, Hamari, Joaquim, et al. (2022) who find no main effects on students' perceived flow between personalised and non-personalised gamification. They suggest that personalising game elements according to the dominant gamer type profile may be not enough to improve user experience. We show in this study that even taking into account a more complete profile, and not only the dominant player type, is not enough to improve learner motivation.

Regarding more specifically the second period of the experiment, the increase of learners' *intrinsic motivation for stimulation* and the small increase of *intrinsic motivation for knowledge*, whether the elements are adapted or not, show that, at the end of the experiment, learners were having more fun and were more interested in learning maths.

On the other hand, learners were less motivated to do the mathematics exercises for *a sense of accomplishment*. The high decrease in this type of motivation could be explained by the increase in difficulty in the learning content (as designed by teachers), meaning that it might have been too difficult for them and they did not succeed in overcoming the challenge.

Regarding the rather small decrease in *external regulation*, we can assume that it is associated with the increase in *IM for stimulation*: after several lessons, learners used more the environment for fun than for external rewards, they got caught up in the game. Also, as learners did not receive any grades for the quizzes during the experiment (a choice made by the teachers for the experiment so that learners would not be distracted by their grades), they were not focused on such an external reward.

The high increase of *amotivation* shows that learners felt like they had less reasons to do the mathematics exercises. This result is similar to that found in a previous study we conducted using the same gamified environment (Reyssier et al., 2022) and in another study conducted with a gamified learning environment dedicated to learning French grammar based on repetitive exercises (Lavoué et al., 2019).

It could be explained by a weariness effect due to the fact that all the sessions are about the same lesson (no novelty of course discovery) and based on the same type of exercise (quiz). This would imply that gamification could not compensate for these detrimental effects on motivation, which are due to the nature of the learning activity itself. This result is consistent with the rather small decrease in *identified regulation*:

learners may have found less purpose in doing quizzes after several sessions, meaning that the game elements were not sufficient to maintain this type of motivation.

The significantly higher decrease in identified regulation in the second period for learners who had adapted game elements compared to other learners, may reveal a detrimental effect of adaptive gamification on the importance of the activity itself as perceived by the learners. They may be more involved in the gamified process than in the learning activity. At the same time, it is noteworthy that in the second period of the experiment, the adaptation of the game elements had a significant positive effect on *introjected regulation*, while the randomly assigned game elements did not. This increase in learners' sense of self-esteem (Vallerand et al., 1992) could be explained by game elements that, when adapted, gave a more positive or a more appropriate feedback to learners.

Regarding other similar studies, we cannot compare directly with those found in the related literature (see section 2.2), as most of the studies did not investigate in detail the different types of motivation, focusing on *intrinsic* vs. *extrinsic* motivation as a whole. As we tracked a wide variety of motivation types, we were able to show more precise variations in learner motivation. Nonetheless, if we consider a global trend in the variation in *intrinsic* motivation, especially the decrease in *IM for accomplishment*, our results are in line with other studies that showed a general decline of *intrinsic* motivation after a long term (Hamari, Koivisto, & Sarsa, 2014; Hanus & Fox, 2015). On the contrary, the study reported in (Rodrigues et al., 2021) showed an increase in *intrinsic* motivation on learners familiar with the learning topic. These differences in findings between studies could be explained by different contexts and duration.

In a recent study conducted in similar conditions (Reyssier et al., 2022), we showed rather similar trends in the variations of learners' motivation, with a significant decrease in *IM to knowledge* and in *external regulation*, as well as a significant increase in *amotivation*, after using the gamified environment during ten lessons. This new study differentiates the results according to whether the elements are adapted or not, showing that the trends are similar. This represents an important finding in the field of adaptive gamification.

### *7.2. Effects only visible after several lessons*

When considering both conditions, whether the game elements are adapted or not, we saw significant effects on learner motivation only during the second period of the experiment, except for *identified regulation* with non adapted game elements. This may be due to several reasons: first learners could have been affected by a novelty effect of introducing a new technology in the classroom, second the learning content increased in difficulty the further learners progressed through the quizzes.

In their normal lessons, teachers did not use tablets, mostly due to not having access to this kind of devices, but also due to not having adequate learning software. Therefore, introducing these devices for this experiment could have caused a novelty effect on learners. Several studies discuss how a novelty effect could lead to positive effects of gamification that would not necessarily continue overtime (Hamari et al., 2014; Koivisto & Hamari, 2019; Seaborn & Fels, 2015). During the first period of the experiment, learners were still discovering the learning content and their game elements, thus keeping their motivation at a rather stable constant level. The novelty effect may have wear off after the first period, thus giving way to the significant variations in motivation we observe in the second period. This novelty effect is often raised in gamification studies (Hallifax, Serna, Marty, & Lavoué, 2019; Hamari et al., 2014) as a reason why shorter studies fail to show the more complex results that can be observed in longer studies. Several longitudinal studies corroborate that gamification suffers from the novelty effect (Rodrigues et al., 2022; Sanchez, Langer, & Kaur, 2020).

The participating teachers designed the learning content to be as close to what they would normally do in their class. Therefore, each new lesson would introduce a new learning concept and make learners apply it in the quizzes. This naturally meant that the later lessons were harder than the earlier ones. This could lead learners to have a harder and harder time with the questions, potentially causing more marked effects on motivation during the second period of the study. This would confirm our interpretation in previous section of the significant decrease observed particularly in *IM for accomplishment*. Accordingly, Landers et al. (2017) showed that Leaderboards were less effective when the difficulty increased.

When comparing to the results of the study conducted by van Roy and Zaman (2018), our findings are quite different. They observe a significant decrease in all types of motivation and an increase in *amotivation*, mainly during the 10 weeks of the online course, and then a slight increase in all types, except for *amotivation* that decreased. They also identify a highly personal effects on *intrinsic* motivation (with both increases and decreases depending on the individual learner). These differences in the results can be explained by a difference in participants (students in secondary schools, compared to university students), and different learning situations (in class over eight lessons and four to six weeks, compared to 15-week semester of a master course). Nevertheless, these two studies confirm the need to observe learners' motivation not only as an outcome, but also as a process that evolves over time.

### *7.3. Individual game elements impacting learners' motivation differently*

As shown in section 6.3, game elements have different effects on learners' motivation depending on whether they are adapted to their profile or not.

Considering the **Avatar**, we notice that the negative effects on *IM for accomplishment* and *amotivation* strongly increased and that these differences were significant in comparison to the non adapted condition. We can associate these results with an increase in the other two types of *intrinsic* motivation, thus showing that adaptation succeeded in making the activity fun and leading learners doing the activity for learning mathematics, even if they may have felt less competent to master the exercises at the end of the course. It has been shown in several studies that the Avatar game elements matches the need for autonomy regarding the SDT (Sailer et al., 2017; Zainuddin et al., 2020). This could explain its positive effect on two types of intrinsic motivation.

The adaptation of the **Timer** game element was a success, by removing the detrimental effects of this element when it is attributed independently of the student's profile, while increasing learner's enjoyment of the learning activity. As we would expect, they were not motivated by external rewards (no rewards are associated to this element). We believe that the Timer, when assigned to specific learners, encouraged them to challenge themselves, and thus helped them gain a greater feeling of *competence*.

Finally, the **Progress** game element, when adapted, had a significant negative impact on four types of motivation, similar to the non adapted condition (the variations in motivation are not significantly different between both conditions), without the positive effect observed on *IM for stimulation* in this second condition.

These results are quite surprising as similar game elements are frequently recommended for various player types (never all of them though) (Hallifax, Serna, Marty, Lavoué, & Lavoué, 2019; Orji, Tondello, & Nacke, 2018; Tondello et al., 2016). Furthermore, this game element matches with the need of competence regarding the SDT (Seaborn & Fels, 2015; Zainuddin et al., 2020). However, we showed in a previous study conducted with the same learning environment and in the same context that Progress has detrimental effect on the *intrinsic* and *extrinsic* motivation of learners that are initially intrinsically and extrinsically motivated (Reyssier et al., 2022). We identify two possible explanations for this result. First, the design of this game element may not be meaningful enough to students. Second, our adaptation algorithm may not be sufficiently appropriate to balance the negative effect on motivation with a positive effect considering the player types. Further studies should be conducted specifically on the adaptation of this specific game element.

## 8. Limitations

Whilst we tried to ensure that our study and results are as generalisable as possible, we can identify a few limitations that should be mentioned here. First, it is noteworthy that our adaptation algorithm did not assign badges, leaderboard, or points to any of the participants, although we integrated them in the gamified platform. These elements are, however, the ones most frequently used in gamification (Subhash & Cudney, 2018). This can be explained by the majority of neutral (for badges) or negative influences exhibited by these game elements in a previous study conducted with the same gamified learning environment, in a similar context (same learning content and game elements, same aged learners) (Reyssier et al., 2022). Meanwhile, the fact that our algorithm is based on data from this same experiment, and has been validated by a simulation (Hallifax et al., 2020), ensures that it is applicable to this context. This point is all the more important if we consider the situational and contextual levels of intrinsic, extrinsic and amotivation (Vallerand, 1997).

Second, while we focus specifically on secondary school level Algebra, it may be possible that results may vary with a different subject, with learners of another age and in another domain than education (Hallifax, Serna, Marty, Lavoué, & Lavoué, 2019). This limits the generalisability of the specific results obtained in this context, whilst our findings on adaptive gamification raised the need for more studies in other contexts.

Third, as pointed out by (Lessel, Altmeyer, Schmeer, & Krüger, 2019), the effect of gamification widely varies for willing participants (i.e. participants performed better when they had a choice in using the game elements). Learners in our study were assigned game elements either at random or based on their learner profile, but they were not able to choose their game element. It is possible that if they were allowed to select their game element (say for example amongst the top 2 or 3 game elements for their profile) this might have had a better effect on their motivation.

Finally, we specifically made the choice to not include an un-gamified control situation as we were interested in evaluating how effective the adaptation was on engaging learners and not the gamification itself, since the question of how effective gamification can be is something that has been widely investigated in the related literature (see section 2.2).

## 9. Conclusion

In this paper, we presented the results of a large-scale study on the impact of a gamified learning environment on learners' motivation, looking specifically at how adapting to learners' player profile and initial motivation for mathematics affects seven different types of motivation. Our study covered eight lessons, composed of several quizzes (4 to 10) on the topic of secondary school level basic algebra. We analysed survey answers from 121 learners that used the gamified platform for between 4 and 6 weeks as a part of their normal class sessions.

These findings provide some insights into how adaptive gamification impacts specific types of motivation over time, opening up new research avenues in the field. First, we showed that the effects of the use of the gamified environment were only visible in the second period of the experiment, after five lessons. We therefore recommend that future studies, or uses of gamification, be considered only in longer settings (i.e. more than 2-3 weeks). This recommendation would ensure that the gamification mechanisms have time to properly impact learner motivation.

Second, we showed that the impact of gamification (either adapted or not) is different when considering each type of motivation. In both conditions, we observe a positive effect (increase in stimulation, and increase in internal regulation) and a negative one (decrease in accomplishment, identified regulation, external regulation and increase in amotivation). Our results reinforce the idea that future works should consider motivation with a multi-dimensional approach, which would allow to observe more specific effects of gamification on learner motivation and to achieve a better understanding of gamification.

Third, we showed that even if we do not observe significant differences between the two conditions, adapting gamification to learners seems to reinforce the effects on their motivation. We also showed that different game elements have different effects on learners, and that these effects differ depending on the type of motivation. In particular, non-adapted game elements had no or mostly negative effects, whereas when adapted, Avatar and Timer had both some positive and negative effects on different types of motivation. Progress, instead, had mainly a detrimental effect on different types of motivation, even reinforced when adapted. Further studies are therefore needed to identify the factors to consider for adaptation, as well as the interactions between the different types of motivation that are impacted by each game element.

In conclusion, adaptive gamification is a growing field of research that needs to mature and further studies need to be conducted to make comparisons between contexts, ans between factors to be considered in order to adapt. Through this study we highlight the need for running long term studies, and the importance of considering multiple types of motivation, relying on the Self-Determination Theory. Our future works will be directed towards the dynamic adaptation of game elements, taking into account learners' behaviours during the course.

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## Appendix A. Profile questionnaires

The Academic Motivation Scale (AMS) (Vallerand et al., 1992) evaluates the seven types of motivation described in details in section 2.1, except for integrated regulation. We provide an example of one of the questions asked for each dimension:

- **Intrinsic Motivation for Knowledge**, i.e. performing an activity for the pleasure and satisfaction of doing something new: *"I like learning new things"*
- **Intrinsic Motivation for Accomplishment**, i.e. performing an activity for the pleasure of overcoming a challenge: *"I like to see that I am able to solve problems"*
- **Intrinsic Motivation for Stimulation**, i.e. performing an activity for fun or excitement: *"I really like maths"*
- **External Regulation**, i.e. performing an activity to gain some kind of external rewards: *"I want to get a good grade"*
- **Introjected Regulation**, i.e. performing an activity to avoid shame or increase self-esteem: *"I want to prove that I can do well in maths"*
- **Identified Regulation** i.e. performing an activity in order to achieve precise objectives: *"I will be able to choose my future studies thanks to maths"*
- **Amotivation**, i.e. the absence of intention to perform an activity: *"I don't know why I got to maths class, I feel like I'm wasting my time"*

The Hexad typology differentiates six dimensions (Marczewski, 2015). We provide an example of the statements asked for each dimension:

- **Socialiser**, motivated relatedness. They want to interact with others and create social connections: *"Interacting with others is important to me"*.
- **Free Spirit**, motivated by autonomy and self-expression. They like creation and exploration: *"It is important to me to follow my own path"*.
- **Achiever**, motivated by Mastery. They want challenges to overcome, they are looking to learn new things and improve themselves: *"I like overcoming obstacles"*.
- **Philanthropist**, motivated by purpose and meaning. Their goal is to help others with no expectation of reward: *"It makes me happy if I am able to help others"*.
- **Disruptor**, motivated by change. In general, they want to disrupt the system, either directly or through other users, to force positive or negative change: *"I like to provoke"*.
- **Player**, motivated by rewards and his/her personal success: *"I like competitions where a prize can be won"*.

## Appendix B. Adaptation algorithm

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**Algorithm 1:** Compromise algorithm

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*Initialisation – Sort both affinity vectors in decreasing order of affinity*

$affVecHex$ ← sorted Hexad affinity vector
$affVecMot$ ← sorted initial Motivation affinity vector
*These vectors are structured using the following format: [(gameElement,affinity), (gameElement,affinity)...]*

$overlap$ ← positive overlap between $affVecHex$ & $affVecMot$
*This contains a list of all game elements that have a positive affinity in both $affVecHex$ and $affVecMot$*

```
if overlap is not empty then
    if overlap contains exactly one element then
        Suggest element in overlap[0]
    else
        Add the rankings for each game element in overlap from affVecHex & affVecMot;
        if one game element has smallest combined ranking then
            Suggest that element
        else
            Add the affinities for each game element in overlap from affVecHex & affVecMot; Suggest game
              element that has highest combined affinity
else
    Add the rankings for each game element from affVecHex & affVecMot;
    if one game element has smallest combined ranking then
        Suggest that element
    else
        Add the affinities for each game element from affVecHex & affVecMot; Suggest game element that
          has highest combined affinity
```

---

**Figure B1.** Compromise algorithm