
The Design of a Gamification Algorithm in a Music Practice Application

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ABSTRACT

Keeping track of pupils' progress across different instruments and lessons, and what they are meant to be practicing, can be challenging. The typical solution is to use a book in which teachers write notes and pupils record practice. This can, however, easily be lost or become illegible. Furthermore, music education and self-directed practice is one area of education which is not widely gamified, with gamification describing a technique that drives specific human behaviors, motivates users, and has proven success in influencing learning. An application could therefore be created to respond to these needs by recording and tracking music practice whilst also gamifying student learning. An algorithm which accommodates these requirements is presented in this paper.

TYPE OF PAPER AND KEYWORDS

Short Communication: *gamification, algorithm, motivational affordance, music practice, music application, education, social issues, virtual badges.*

1 INTRODUCTION

With the lead author of this work operating both in music teacher and student roles, he has first-hand experience of the fact that keeping track of pupils' progress across different instruments and lessons, and what they are meant to be practicing, can be challenging. The typical solution is to use a book into which teachers write notes and pupils record practice. This can, however, easily be lost or become illegible; additionally, it does not allow a consistent view of developmental achievements across the whole class from both the teacher and the student perspective. There are therefore benefits to having an electronic system in place to record music practice.

Furthermore, music tuition and self-directed practice is one area of education which is not widely gamified. *"The goal with gamification is to drive a specific behavior and motivate the users of a gamified system"* [10]. While a couple of rudimentary music practice

tracking applications exist, few have been identified which incorporate gamification. In general, applications allow musicians to record practice, with additional features like audio recordings and metronomes as in [5]. A number do not, however, exploit mechanisms such as leaderboards or virtual badges to encourage practice and competition. This represents a limitation in the technologies available, given the proven benefits of gamification in supporting student learning: A better learning experience can be created if students have fun, and a good gamification strategy will give high levels of engagement - it can provide instant feedback so that students know what to improve on, as well as being motivating to students when they see that they are continually getting better. Gamification can prompt behavioural change through the use of badges and leaderboards to aid practicing the right thing.

The proposal in this paper is therefore to build an application which responds to this gap. It will be

accessible from mobile devices and can run natively as a website, supported by a back-end database. Using the application, teachers can set practice work for students and, in turn, students can record progress. By using the application, teachers would know what to focus on in further lessons. As a gamification strategy is also a feature of the system, enabling students to compete against each other when learning new pieces of music and/or scales, students can then track their progress and compare it with others. Students can gain virtual badges when the teacher marks items as being learnt, with the overall effect of incentivising students to practice.

In this paper, we firstly present the requirements of this system which have been gathered from music teachers and students. We then consider how these requirements can be used within an implementation by designing the classes; relationships between the classes are explored using an ER diagram. This is followed with a description of the gamification algorithm, which details how points and badges may be earned as part of the gamification function. Finally, the pseudocode of the system is used to explain how the motivating element of gamification is achieved.

The remainder of the paper is organised as follows: In Section 2, a review of the literature is presented, in which the state-of-the-art in gamification is provided with a view to understanding the most positively influential mechanisms. This is followed in Section 3 with the design of the gamification algorithm, which is proposed in response to the user requirements gathered. In Section 4, the approach used to test the system and ensure that the user requirements have been fulfilled is presented. Social issues of applying gamification in educational applications are considered in Section 5, and the paper concludes and discusses further work in Section 6.

2 LITERATURE REVIEW

The evidence given in [11] is interesting in respect of the work presented in this paper as it reviews the extent to which gamification can be effective in encouraging learning. To understand the utility of gamification in applications which support learning, there are indications that, “*gamification provides positive effects, however, the effects are greatly dependent on the context in which the gamification is being implemented, as well as on the users using it*” [11]. The report covers a review of gamification concepts, within which *motivational affordances* were the most prominent. A motivational affordance in the context of this work is a game element which can stimulate a user’s motivational needs, increasing their enjoyment and engagement. Examples of motivational affordances include points, leaderboards, badges, levels, and feedback. This is especially useful when developing an application as it influences thoughts around which elements of gamification, or motivational affordances, can and should be included.

To understand how to best gamify actions within the application, research was conducted to compare the different motivational affordances identified in the previous paper, and which ones work best for each user action. The discussion in [24] addresses this issue by comparing the outcomes of various rewards and exploring how they affect user actions. However, the paper’s conclusion specifically points out that no legal or ethical issues of gamification or analyzing user data have been covered. Enhancing the findings in [24], this work provides a solution for various designs based on different motivational affordances.

In terms of the various types of motivations available in an application, the core ‘*Taxonomy of motivational affordances*’ in [24] weighs up the mechanics, possible means of interaction between a user and the system, and presents arguments for using each one. As rewards in a system can only generate motivation, they don’t change the ability to perform a behaviour (except if the reward itself is a tool that increases ability). This means that it is important to structure the reward system carefully to make sure that they are not over or underused: Rewards only provide little motivation if they do not have a moment of surprise, e.g., occur in regular intervals and are predictable [18]. Taking this research and applying it in this project will help to determine how and when to reward users.

There are multiple ways by which motivational affordances may be applied in a gamified application. In [1], the authors present a theoretical model of user behavior in the presence of badges. The work gives examples of variables in the model that are considered when designing a gamified application; *Action Types*, *User Histories*, and *Badge Boundaries* are key terms in the modelling of user behavior. These are all considered in the mathematical equations and algorithms that calculate badge weighting and scores, firstly focusing on badges that are awarded once the user has reached a certain level of cumulative contribution. A badge is therefore associated with the, “*subset of possible user action vectors corresponding to contributions that warrant the badge*” [1]. The scope of the work covers a range of ways to calculate when to award badges based on user actions, their actions over a time window, and using this to calculate the Badge Boundary, which is when a badge should be awarded. Alongside exploration of the calculations, probability of the actions was also determined. The paper concludes that badging systems are an increasingly widespread feature of social sites, and they can produce strong incentive effects on users. In the context of the application proposed in this paper, incentivisation may have social implications as it will drive user interaction with the application. Another point reached is that incentivising users to increase their activity brings up the question of how this affects the quality of their actions, but this is not covered in detail.

Other literature has also been identified as useful in the design of a gamified system. The authors of [20], for

example, give sample process models for scoring activities within gamification. Identifying the key elements from this paper allows a process model to be created for the main gamification calculation in the application. This is where students are compared against each other to create a ranking based on their past results, and using a scoring of goals and badges. It has been possible to work out how to score students based on 'goal representation', which is explained in [19] as follows: "Since scoring criteria need to be defined with respect to goals, an important decision concerns which goals are to be taken into account" [19]. This paper links well with research in [24] because this is where choices will be made in the project's application, around which rewards are considered suitable for activity types. Process figures and calculations integrate parts of the model such as *quality standardisation* and *scale conversion*.

With an understanding of gamification mechanisms in general, it is useful to consider how these are used in systems which have been developed specifically for the purpose of teaching music to students, which is the core goal of the development presented in this paper. In [22], the author explores student perception of gamification in music practice in comparison to video game playing. The author identifies that the concept of flow is crucial in achieving the objective of gamified systems, and subsequently performs a study to observe the effects of flow in video games and how, if possible, it can be reflected in the support of music practice. Students were interviewed in four respects after taking part in sessions of gamified music practice and video game playing. The metrics on which they were assessed include Lived space ("What was going on around you?"), Lived body ("How did it feel in your body?"), Lived time ("How did you experience the passage of time?"), and Lived human relationships ("Who did you talk to about this before or after?") [22]. The author identifies that students have flow-like experiences more frequently during video game play as opposed to during piano practice. This is a consequence of the fact that students generally perceive piano study as real life and not game play. Recommendation from this paper is therefore that gamification may be inappropriate to support music practice. This is a consequence of the fact that some students express embarrassment regarding game play, while the opposite is true of piano practice.

It is a common impression that, "Computer games can be used for educational purposes in order to make learning fun and teaching more effective" [22]. However, the author of [22] identifies through the study that this is not uniformly the case, with music practice at least. This finding may be specific to the fact that students who participated in the study are video game players; there is evidence in other pieces of literature that students indeed do benefit from gamification of their music practice sessions. In [23], as an example, the authors develop a game to support students learning music which asks them to identify an incorrect note in a played melody in

relation to reading the melody's sheet music. The game difficulty is adjusted dependent on the user's performance. The success of the gamification mechanism in this system is measured by the duration of time spent playing the game and the speed with which students progress through difficulty levels. The results show variable success: A relatively large number of participants in the study did not show improvement in their performance, although the authors correlate this with the duration of time spent practicing, and the relationship between time and performance. The variable and inconsistent nature of results, however, is demonstrated in the fact that some students achieve a large increase in performance despite playing the game only for a short period. Further investigation reveals that good performance with short practice time was achieved by students with a music background. The study also found little correlation between difficulty level and performance improvement, supporting the system's utility at all levels. The results presented in the paper therefore do not strongly verify the suitability of gamification as a tool which supports learning.

The authors in [4] propose a game which tests students' musical ability to replicate a melody. By completing a series of gaming movements and avoiding obstacles, the student will gain access to a bonus level. It is within this bonus level that they are tested on their ability to replicate the melody and, once complete, return to game play. The suitability of the game to achieve its learning objective is assessed to a limited extent.

In [2], the author explores the use of gamification to help students practicing scales, chords and arpeggios. Gamification mechanisms used include rewards such as points, badges and levels, avatars, and the ability to give progress updates to others. These were allocated to students using an application called 'Technique Tower', in which students are given the overall goal of reaching all levels of the game. It is possible to progress from one level to the next by achieving technical competence in an area of their choosing from a chart of requirements for their level; points are awarded by the teacher once competence has been demonstrated. A trophy is earned when progressing between levels. From a study carried out, it was possible to identify that students participating in the gamified system became more competent in technical exercises than those who did not.

Beyond the music domain, gamification is a technique used to motivate in many others. A platform which incorporates gamification to support more general learning across modules is proposed in [7]. The objective of this platform is to facilitate a flexible structure whereby the instructors can choose to apply the gamification mechanisms which they feel most suitably meet their requirements, from a list which includes course activities and exercises, quizzes or exams, immediate feedback, and a reward such as points, badges, or virtual currency. The objective of the design of this platform is to facilitate the various psychological

needs of motivation, which include autonomy, competence, and relatedness. The key feature of this system is the ability to customise the course content specific to the needs of the module, and to turn any game element on and off. The aim of this flexibility is to explore the effectiveness of the simultaneous use of different gamification mechanisms.

Gamification is recognised in [13] as a tool which can be exploited to encourage user engagement with government practices to build sustainable communities. To achieve long-term results, it is important that the needs of citizens are reached: gamification can provide one approach to meet users' needs for enjoyment while fulfilling the more serious input from government. The authors propose a mechanism which incorporates self-determination theory and organismic integration theory, among others, to provide intrinsic and extrinsic motivation to engage. Gamification provides motivational affordances which facilitate reward-based gamification. Intrinsic rewards are facilitated through autonomy, purpose, mastery, and relatedness, among others. For effective engagement in the process overall, participants should be provided with information, and possess qualities of interactivity and reflection.

A mechanism is presented in [17] to support learning of AutoCAD, a tool to create architectural drawings. Users are paired up with another, to create a competitive element. They then compete to complete a task. In one version of the game, a component can see a split screen of their opponent, who is simultaneously completing the same task. In another version, a player can observe the opponent's video after completing their own task. The authors carried out a number of experiments with a user group. In response to one experiment, respondents found that the learners had difficulty in learning from an opponent's video at the same time as working on their own task. They did, however, find watching the replay of their opponent completing the task useful.

3 DESIGN OF THE GAMIFICATION MECHANISM

The design of the gamification mechanism proposed in this paper is presented in Section 3 from the perspective of the user requirements which have been gathered, presentation of the requirements as user stories, and mapping the user stories against one another using an Entity-Relationship (ER) diagram.

3.1 Requirements Elicitation

A set of requirements were gathered by talking with project stakeholders, including two music students and two teachers. The stakeholders were asked about problems faced in relation to: a) practicing music in general, and b) getting students to practice music. The stakeholders' input and requirements have been captured as *user stories*, which cover why and how each user

interacts with the application, and is a high-level definition of what the application should be doing. *Acceptance criteria* have been included, which determine when the application has satisfied the user story. The system requirements follow:

System Requirement ID: 1

Originator: Teacher

Description: I want to be able to create practice items (pieces) for my students

SO THAT they know what they are meant to be practicing

Acceptance criteria: practice items can be created with a Name, Date, ID, and are assigned to existing students.

System Requirement ID: 2

Originator: Teacher

Description: I want to be able to view a student's progress on music

SO THAT I know what to teach the following week

Acceptance criteria: Student progress against practice item can be retrieved using a Student ID and Date.

System Requirement ID: 3

Originator: Student

Description: I want to be able to see my progress against other students

SO THAT I know how I am doing and can practice harder.

Acceptance criteria: progress can be calculated and retrieved for one student against other students using a Piece ID or Practice Set ID and returned to the Student.

System Requirement ID: 4

Originator: Teacher

Description: I want to see the average time taken to practice a piece

SO THAT I can see how students are progressing

Acceptance criteria: average time taken can be stored against pieces in the system using a Piece ID and existing practice information in the system.

System Requirement ID: 5

Originator: Teacher

Description: I want to remove pieces from practice sets once they are complete

SO THAT new pieces can be assigned

Acceptance criteria: pieces can be removed from a practice set once complete using a Piece ID.

System Requirement ID: 6

Originator: Student

Description: I want to be able to see a history of my progress

SO THAT I can see how well I have done

Acceptance criteria: history of progress can be displayed. Practice items can be moved to 'history' once complete.

System Requirement ID: 7

Originator: Teacher

Description: I want to be able to set expected completion targets

SO THAT students will have targets to reach which will inspire practice

Acceptance criteria: targets/gamification targets can be set by teacher for student/students/practice sets. A model for gamification will have been created.

System Requirement ID: 8

Originator: Teacher

Description: I want to be able to set the reward level for pieces **SO THAT** I can adjust the gamification mechanism to different standards

Acceptance criteria: gamification can be adjusted by Teacher for different pieces for different students. A model for gamification will have been created.

System Requirement ID: 9

Originator: System Requirement

Description: New students can be created **SO THAT** they can be assigned practice items

Acceptance criteria: New students can be created by the system with a Name and an ID.

System Requirement ID: 10

Originator: System requirement/Teacher

Description: New practice sets can be created **SO THAT** items can be added to them

Acceptance criteria: new practice sets can be created and items can be added to them. Practice sets are created with a date and return an ID. Existing pieces or new pieces can be added to the set.

3.2 Representation of System Requirements

We use the Entity-Relationship (ER) diagrams to represent the system requirements. Sketches of ER diagrams facilitated building of a REST CRUD (Create, Read, Update, Delete) interface for the main objects (Students, Teacher, PracticeSet). To consider a couple of the system classes (Figure 1) in detail: `PracticeWeek`

is a class that contains an element called `PracticeItem`, and this in turn uses a class called `PracticeSession`. The ER diagram does not make specific allowance for scales: Scales can have an ID, Name, Score and Difficulty, so they can be modelled as `Pieces`.

`Score` and `Difficulty` are two attributes that warrant further explaining: `Difficulty` is a value assigned by the Teacher when the piece is created in the system. The value is set for each piece and does not vary depending on the student. This value can be interpreted in the same way as a Grade, for example Grade 5 or Grade 8, which indicate a standard of ability. `Score` is the value and achievement of completing the item, and counts towards the student's overall score. An example of where these attributes are used is in the *Completing Pieces* activity:

When a piece is marked as complete, the `Difficulty` of the piece is divided by the student's average grade. This is then multiplied by the piece's total achievable score, before being added to the existing score. There is also a Boolean flag for whether the piece forms part of a suite and then the ability to add IDs of other pieces that contribute to the suite. This has been added to the system so that badges, a motivational affordance within the context of the gamification aspect, can be awarded if a student completes a suite of music.

`Pieces` map to `PracticeSessions`. Figure 2 includes a representation of how this information could look in a table, in a simplified implementation of a User Interface (UI).

3.3 Gamification Algorithm

An algorithm has been defined to calculate student scores for presentation on a leaderboard. Students achieve a position on the leaderboard which is dependent on the number of points they have earned, with the more points enabling a higher position on the leaderboard. This calculation uses the student score awarded for activities and achievements, and combines this information with any badges awarded. Using research from [20], and building on the process model developed here, *activity types*, the activities with which users are involved with, have also been derived for this application:

1. Students earns points by:
 - a. *practicing daily*. A daily record of progress in practicing a `Piece`, recorded in relation to `PracticeWeek`.
 - b. *completing pieces*. A `Piece` is *complete* when it has been marked as being completed by the teacher. This marking is applied to the piece and will stay in the student's practice history.

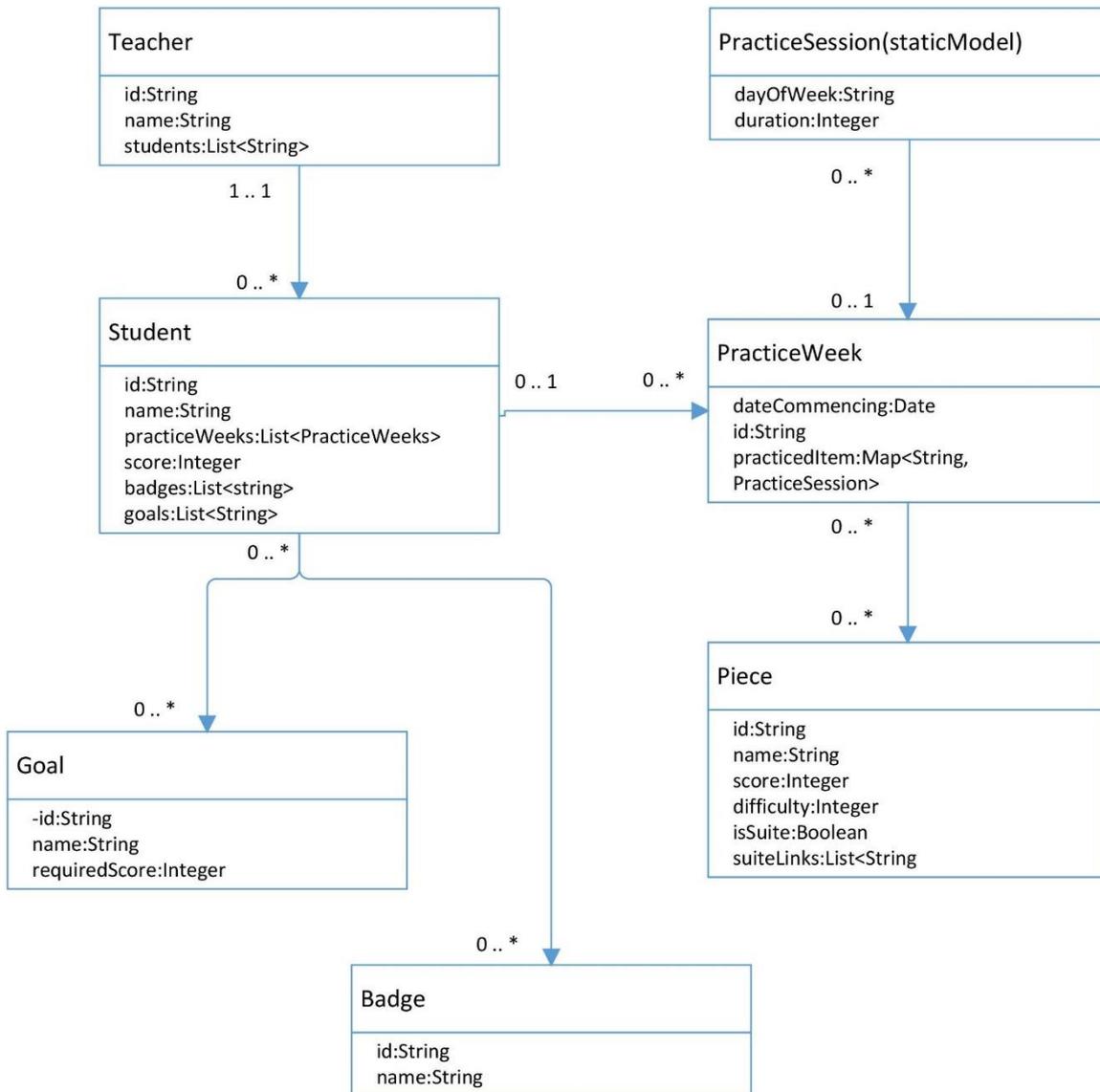


Figure 1: Entity-Relationship diagram of the system requirements

2. Students earns badges by:

- a. *completing several pieces*. This can be a set of pieces in a suite, or milestones such as ten pieces completed, fifty pieces completed, for example. This is not time-bound.
- b. *maintaining a constant practice history*. A record of practice is kept and an average is calculated to determine if the student is making steady progress. This is measured over a period of time, such as practice time recorded within a week or a month.
- c. *completing a suite of pieces*. Pieces are *linked* if they are part of a suite. If a student completes a Piece, the algorithm will check to see if other pieces in this suite have also been completed.
- d. *completing a new piece in a set period*. Calculated using the student's average grade and difficulty rating of the Piece, which is compared against how long they have been practicing before being *completed*.

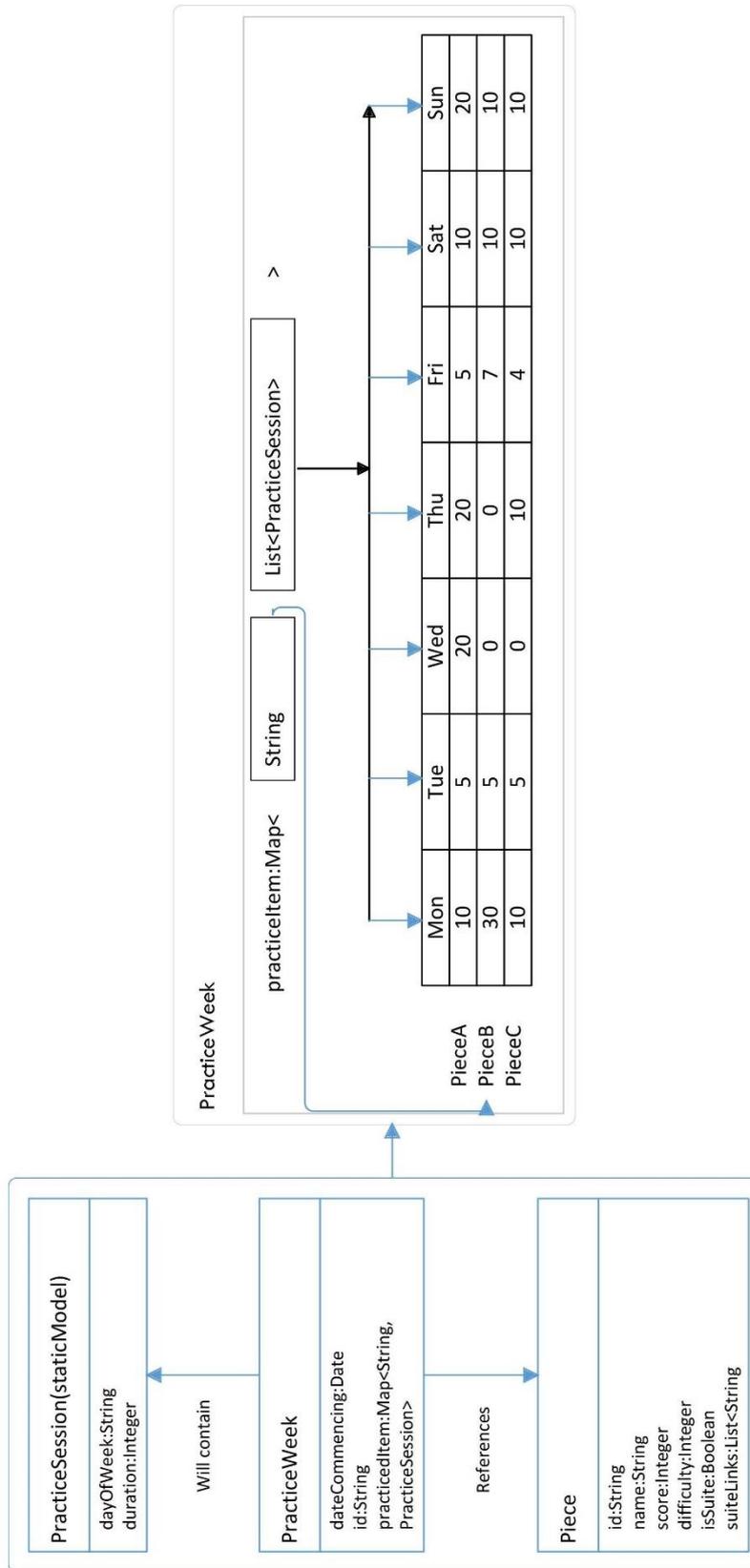


Figure 2: Model of PracticeWeek map

The next step in the gamification process is to add the *quality standardisation*. As Schieder et al. writes in [20], “Qualities can be standardised in different ways, by comparing them to: (1) the past, to measure individual change (e.g., reduction of CO₂ emissions); (2) the behaviour of others, based on leaderboards, or other types of statistics; (3) established norms, e.g., CO₂ emission contingents can be based on the CO₂ standard of temperature rise; (4) a set of conceivable alternatives”. In the latter case, we standardise qualities of activities with respect to what a user might have done instead, given his or her own goals. The solution presented in this work has been interpreted against (4), and values are standardised based on what a user might have alternatively done. For the gamification, this is where the current value in question (for example, points earned) is compared with other values such as the student’s past scores, individual change, the behaviour of others in the system (for example, if the student is earning more or less than other students on a daily basis), or the leaderboard (how many points do they have in total, what is their position compared to their classmates, which can be used as a ranking). Once student results are standardised, the criteria can be constructed.

The *criteria construction* assesses the extent to which the values of qualities contribute to a goal. For example, what has the student’s performance been over time or what are the percentages of an expected value such as expected time to complete a piece. For example, in the case of *Suites*:

Take the average time to complete across a suite and, if the student is in the 80% boundary of that average time, (at) they can gain the reward for completing a suite.

The average time can be calculated by reviewing all students who have completed that piece and how long it took them.

Criteria integration is the next stage. This refers to, for example, comparing a student directly with another student based on their overall score on a leaderboard of how many badges or goals have been collected. This is linked with *scaled levels*, which refers to the fact that not all badges are the same and there should be some way of distinguishing this. A badge awarded, for example, for ‘completed 1 week of practice’ is not the same value as ‘completed 100 weeks of practice’. This corresponds with the opinion in [22] that it is reasonable to, “set tasks that students understand and in which they can reasonably hope to achieve success, but that are also in their zone of proximal development”.

A breakdown of the calculations for each of the actions that have the most modelling with regards to the *quality standardisation* and *criteria construction* are presented in Appendix A. The way in which these are combined to reach a student’s overall score are presented in Figure 3.

4 TESTING

The system has been tested using Behaviour Driven Development (BDD), which involves a set of tests written to verify that the functional requirements collected from stakeholders have been achieved. Implementation of BDD involves creating executable tests of scenarios derived from user stories that follow a standard pattern: “given (some context) when (something happens), then (some behavioral validation)”. These tests were written as Gherkin feature files and tested using the Cucumber framework. Gherkin allows the behavior to be described for testing, without detailing how it is implemented. As examples of two tests:

```
@Piece
Feature: create piece
@ID01
Scenario: teacher creates piece
  When I connect as a Teacher
  And I create a "Piece" known as "music-piece-01" with |title|music_piece-01|
  Then the response indicates a SUCCESSFUL CREATION
```

```
@StudentRecord
Feature: Student Record and History
@ID02
Scenario: Teacher getting progress
  When I connect as a Teacher
  And I request a student's recent history with |name|Student1|and the period of |period|1w|
  Then the response contains 1 result with items |PracticeSets, Pieces, Goals, Badges|
```

The @Piece and @StudentRecord annotations specify the resource under test. The @ID01 and @ID02 are the IDs of the requirements being tested. The feature is the specific part of that requirement. Anything between || is a parameter passed to or from the API/system.

5 SOCIAL ISSUES OF GAMIFICATION

When developing any system that involves human interaction, it is important to consider the negative effects which could arise. In the case of this system, negative effects could result from the use of gamification in education. A leaderboard has been implemented in this system. Research has shown that for students who do not enjoy competition, leaderboards can have a negative impact on motivation [8] [12]. Other studies, however, report that only a minority of students, “expressed discontent with the competitive nature of the feedback” [6]. This aspect of the system design has therefore remained. As part of the gamification of the application,

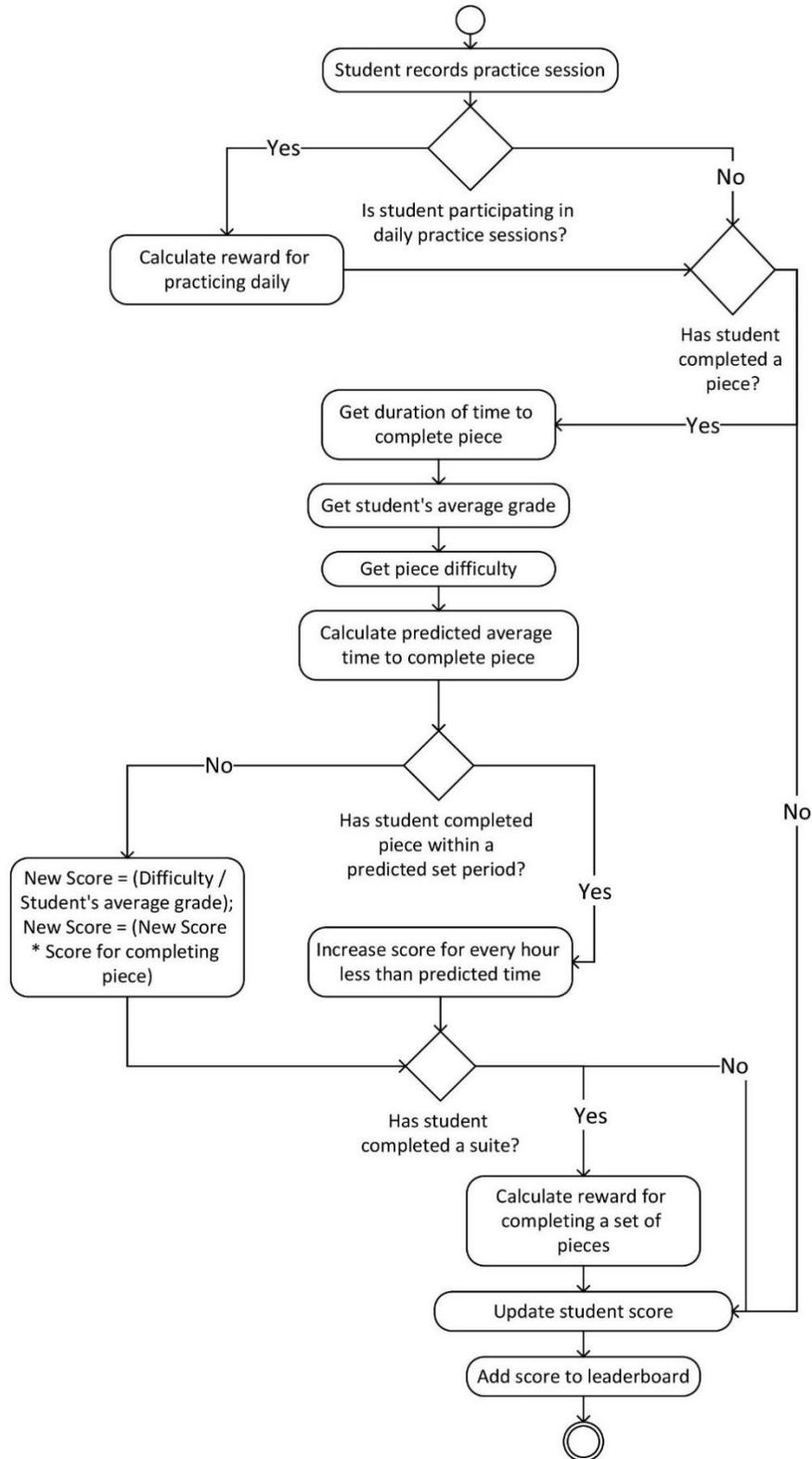


Figure 3: The gamification process of music practice

and part of the algorithm, badges, scores, and goals are built in. Mixed results have been found, however, with respect to the impact of badges and achievements on student motivation and performance at the post-secondary level: Some research has found that badges and achievements support student engagement, while other research finds that there is no impact or a negative impact on student engagement and motivation. Haaranen et al. [9] report that some learners have strong negative feelings about the use of badges in a college course. For this reason, it is recommended that options be built into gamification systems which allow learners to turn off elements such as badges in order to alleviate the social issue arising.

Age and gender can also play a role in the popularity of gamification as a technique to encourage motivation. Reported in [16], the gaming domain has traditionally been more popular to young males; it is interesting to read the authors also noting that, by 2011, gaming users on social networks were women in their 30s and 40s [16]. By 2017, males continue to dominate at all age groups, excluding the 51-65 age group, for which 7% of gamers are male and 8% are female [21]. In all other age groups, there is a small degree of variation between the male and female gamers, with the heavier weighting belonging to males. The applicability of gamification mechanisms can therefore be affected by the demographics of users, a social issue which is more challenging to control. This fact is reinforced by Jenkins (2016) in [14], who captures that a 'one-size-fits-all' approach is inadequate when applied to a gamification mechanism, and that it is important for a system developer to know their audience such that the technique may be applied more appropriately.

As a further social issue, some authors consider gamification to be exploitative, by providing rewards which are of little use [3]. This is particularly true when gamification is applied in the workplace. It is the opinion of Kim (2015) [15], for example, that gamification can be compared to being a child in school where, for good behavior, the child is rewarded with a sticker – while this might be satisfying for a child, it is of little consequence to an employee. Exploitation may, however, be considered to occur when one party has an unfair advantage over another [15]; while gamification in this context may not be exploitative, it is unlikely to have motivating benefits. To be effective in the learning domain, on the other hand, it is important that the gamification mechanisms are tied to learning objectives to ensure that the rewards are valuable to learners.

6 CONCLUSION & FURTHER WORK

The background research validates the value of gamification as a tool to facilitate learning, and an application specific to the music education domain has been proposed in this paper. It has been recognised, however, that the use of such techniques should be

applied with care in light of social issues in order to ensure that a positive impact is achieved. The background research identified that some learners have strong negative feelings about the use of badges in college courses. As part of the system, it would therefore be beneficial to be able to turn off elements and/or choose from possible options. For example, badges could be turned off as a feature and only a subset of the possible motivational affordances used depending on the situation. These aspects will be explored in future work.

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Appendix A: Pseudocode of the Game Algorithm

In the Appendix A, the processes which are executed to calculate the attributes applied in the quality standardisation and criteria construction are presented.

Activity: Practicing Daily

Activity Data:

If the student records practice for a new session, points are added to the student's score.

Quality Standardisation and Criteria Construction:

The duration recorded for a practice session will be divided by a base number, 10, and rounded. Retrieve the record for the previous day and see if practice was carried out.

Criteria Integration:

If practice carried out on the previous day, the duration is added to the student's existing score. If not, check if this is the same as the average practice time. If it is, then this is halved and added to the student's score. If it is double, then do not half and award the full score.

```
Input: Session time T, Student S
Output: New Score NS
1: BEGIN
2: SET PT = Student S last practice session time.
3: LET x = 6 // set months for practice time
4: IF PT != 0
5:     LET NS = S.score + (T / 10)
6: END IF
7: IF (PT = 0) &&( T = S. getAveragePracticeDuration(x))
8:     LET NS = S.score + ((T / 10 ) / 2)
9: END IF
10: IF (PT = 0 && (T = (S. getAveragePracticeDuration(x) * 2))
11:     LET NS = S.score + (T / 10)
12: END IF
13: RETURN NS
14: END
```

Activity: Maintaining a Constant Practice History

Activity Data:

From the student's PracticeWeek list, aggregate all of the durations for each day by filtering the map given

Quality Standardisation and Criteria Construction:

Calculate the student's average practice duration for a pre-defined number of months. For each practice duration, check if it is within 20% of the average practice duration.

Criteria Integration:

If more than 80% of the practice durations are within 20% of the average practice duration, award the badge for maintaining a constant practice history.

```
Input: Student S
Output: amended Student S
1: BEGIN
2: LET DPA = new Array // array to hold durations of daily practice
3: LET VPA = new Array // array to hold validated practice durations
4: SET A = S.practiceWeeks
5: WHILE A HAS NEXT; DO
6: SET B = A.next
7:     WHILE B.practicedItem HAS NEXT;DO
8:         SET C = B.practicedItem.next
9:         WHILE C has NEXT; DO
10:             DPA ADD (C.duration)
11:         END WHILE
12:     END WHILE
13: END WHILE
```

```

14: LET X = 6 //set X to 6, for 6 months
15: SET Y = S.getAveragePracticeDuration(x)
16: WHILE DPA HAS NEXT; DO
17:   IF DPA.next IS +/- 20% OF Y
18:     VPA ADD (DPA.next)
19:   END IF
20: END WHILE
21: IF VPA.size IS +/- 80% OF DPA.size
22:   Badge B = new Badge
23:   RETURN B
24: ELSE
25:   RETURN null
26: END IF
27: END

```

Activity: Completing Pieces

Activity Data:

When a piece is marked as completed, new points can be added to the student's score.

Quality Standardisation and Criteria Construction:

The difficulty of the piece will be divided by the student's average grade. This is then multiplied by the piece's achievable score, and rounded.

Criteria Integration:

This score is added to the student's existing score.

```

Input: Piece P, Student S
Output: New Score NS
1: BEGIN
2: SET Difficulty D = Piece.difficulty
3: SET average A = Student.averageGrade
4: SET achievable Score ACS = Piece.score
5: LET Score NS = D / A
6: LET NS = NS * ACS
7: RETURN NS
8: END

```

Activity: Completing a Set of Pieces

Activity Data:

When a Student completes a Piece, check to see if the Piece is part of a Suite.

Quality Standardisation and Criteria Construction:

If the Piece is part of a Suite, get the IDs of the other pieces in the Suite. Search all Pieces marked as completed in the student's PracticeWeek history.

Criteria Integration:

If all Pieces are found, award the badge for completing a set of Pieces.

```

Input: Student S, Piece P
Output: Badge B
1: BEGIN
2: SET Integer C = 0 // counter for the pieces
3: SET Integer F = 0 // counter for if the piece is found
4: SET Badge B = new Badge // initialise a badge
5: WHILE Piece.suiteLinks HAS NEXT; DO //iterate the suite links
6: LET C = C + 1
7: SET pieceLink = Piece.suiteLinks.next //get the next piece
8: SET A = Student.PracticeWeeks
9: WHILE A HAS NEXT; DO //iterate the student's practice weeks
10: SET B = A.next
11: IF (B.practicedItem[pieceLink]) != null //does the practiceWeek have the suite piece
12: F = F + 1 // increase 'found'
13: END IF
14: END WHILE

```

```
15: END WHILE
16: IF C EQUALS F //were all pieces found, did F equal the counter C?
17: RETURN B
18: ELSE
19: RETURN null
20: END IF
21: END
```

Activity: Completing a New Piece in a Set Period

Activity Data:

Get the student's average grade and the piece difficulty.

Quality Standardisation and Criteria Construction:

The average number of weeks to complete a piece is equal to the difficulty divided by the student's average grade, multiplied by 4. Once the predicted number of weeks has been calculated, the student's actual time to complete the piece must be calculated. This can be worked out from retrieving all the items from PracticeWeek and adding the duration together from Practice Session.

Criteria Integration:

Points are awarded or deducted from the score. If points are awarded then the badge is also awarded.

```
Input: Student S, Piece P
Output: Student S
1. BEGIN
2: SET SAV = student.averageGrade
3: SET D = piece.difficulty
4: SET N = piece.name
5: LET PAV =( D / SAV ) * 4) // calculate predicted average time
6: LET HD = 0 // create variable to store historical duration
7: LET NS = 0
8: SET A = Student.PracticeWeeks
9: WHILE A HAS NEXT; DO // iterate the student's practice weeks
10: SET B = A.next
11: IF (B.practicedItem[Piece]) != null // does practiceWeek have the piece
12: F = F + 1 // increase 'found'
13: WHILE B.practicedItem[Piece] HAS NEXT; DO // iterate PracticeSession Array
14: SET C = B.practicedItem[Piece].next
15: HD = HD + C.duration // get duration from PracticeSession
16: END WHILE
17: END IF
18: END WHILE
19: IF HD < PAV
20: NS = S.score + ((PAV - HD)* 5) // add 5 for every hour under predicted time
21: S.score = NS
22: S.badges.add(new Badge) //add new badge to student object
23: END IF
24: IF HD > PAV
25: NS = S.score - ((HD - PAV ) / 4)* 5) // deduct 5 for every 4 hours over predicted
time
26: S.score = NS //increase the student's score
27: END IF
28: RETURN S
29: END
```

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