Towards Model-Driven Gamified Software Modelling Learning

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***Abstract*— Motivated by the success of the applications of gameful approaches in different fields, this research harnesses the engaging nature of games, the effectiveness of pedagogy, and the automation of Model-driven Engineering to propose a framework for model-driven gamified software modelling learning. It is a framework for tutors to create software modelling learning patterns, which later can be transformed to generate software modelling learning games for learners to play. This paper presents the motivation behind the initiation of the framework as well as the problem analysis and the solution overview in realising the framework. The framework is then demonstrated to show how the framework works in producing a game that teaches the concept of substate in statechart modelling. Two forms of assessments are then presented as the evaluation of the framework.**

***Keywords*—model-driven, gameful, software modelling, learning, framework**

I. Introduction

Gameful approach, whether gamification [1], serious games [2], and digital game-based learning [3], have been proven to have significant positive impact on variety of purposes, such as learning, skill aquisitions, engagement, pyschological supports, socialisation, etc. [4], [5]. Duolingo, an application for learning new language (https://www.duolingo.com/), and Re-mission, a game to learn dealing with cancers (http://www.re-mission.net, are two popular examples of the gameful approach. On the other side, the application of gameful approach in software engineering, especially software modelling, only has fewer studies since it's quite new and therefore more studies are needed [6]. This condition encourages us to apply it in software modelling learning, an area which has received little attention for the application of gameful approach so far. It broadens opportunity not only to produce a novel approach to software modelling teaching and learning but also to improve gamification processes through the application of Model-Driven Engineering approaches.

Some works [7], [8], [9], [10] have been conducted to use gameful approach in software modelling context and each of the works addresses different problems using different approaches and game elements. This fact challenges us to develop a more generic approach in addressing software modelling learning, so that tutors do not need to develop individual games from scratch only to address certain topics. Therefore, we propose a framework for teaching and learning software modelling–a framework for tutors to create software modelling learning patterns, which later can be transformed to generate software modelling learning games for learners to play with.

The followings are the organisation of this paper. First, this paper is started with an introduction to the background and motivation of our work. Next, some problems that challenge us in realising the framework are identified and analysed. After that, an overview of our solution–the framework–is described. Afterwards, the framework is demonstrated to show how it works from the creation of a modelling language to playing it in a game. Subsequently, the plan to evaluate the framework is presented and discussed. The paper is then closed with presentation of some related works to position our study in the context of gameful approach in software modelling learning.

II. Problem Analysis

In order to engage continously in an activity, for example learning, learners have to be introduced to new more difficult challenges once their competence grow as implied by the concept of Flow [11]. As the challenges increase their competence will grow as well. In facing the challenges, learners have to be given supports and then reduced step by step until they are capable enough to solve the challenge by themselves as suggested by scaffolded learning [12], [13]. Scaffolding can be performed Therefore, in order to master software modelling, learners should be exposed progressively from simple to complex modelling scenarios and this approach should be able to be expressed by tutors in their learning activity design.

Another challenge is transforming software modelling learning activity into gameful activity. Gameful design steps [14] suggested that in order to apply gamification the core activity has to be identified and then gameful modification could be applied. Similar to many simulation games, the core activites should be the ones that are performed by learners (flight simulators, first-person shooting games, football managers, etc.). Commonly, modelling activities in software modelling are constructing abstraction in the form of 2D diagram using visual modelling languages. Constructing model using diagrams is like playing tile and constrution games (e.g. Tetris and Lego Construction) where elements have to be arranged in such a way in order for game to move forward or complete. It requires designing, planning, and building mental image of

part or overall of solution before executing actions. Model construction is an activity that falls into the category of creating in Bloom's taxonomy [15]. The LM-GM framework [16] maps the Bloom's creating category into design, editing, strategy, and planning game mechanics whose activities are also performed in model construction. Thus, the modelling activity using diagrams could also be used as the game mechanics since the activity is similar to tile and construction games. However, the irrelevant activities should be removed, automated, or already executed so learners can focus on the relevant ones [14].

Therefore, in playing the games, learners are provided with an empty or incomplete diagram and asked to construct or modify it so that it becomes consistent with a given problem description and instruction. We name this kind of play as construction gameplay. Some other forms of play are also feasible to be implemented, particularly if different categories in Bloom's taxonomy [15] are needed to be addressed. For example, learners are provided with a problem description and a number of diagrams reflecting candidate solutions and needs to select the correction solution(s). Other form is learners are provided with a diagram and number of statements in natural languages and needs to select the correct interpretation(s) or statement(s). We called these two forms of play as multiple-choice gameplay. Both are more appropriate if we want to address the evaluating category of Bloom's taxonomy [15].

For the construction gameplay, a graphical editor through which the user can construct/modify solutions is needed. Ideally, the editor should be fully integrated with the game to provide live feedback and an immersive experience (i.e. an alternative would be to ask the user to create/edit models in an existing modelling tool and upload them to the game). If the graphical editors are wanted to be embedded into the game, a standardised way to define the abstract and graphical syntaxes of supported languages is required. Also, for the constructive gameplay there are more than one ways to assess consistency and correctness. One option is to require that the provided diagram is a 1:1 match with a reference solution provided by the game designer. A more relaxed approach is to only require that the provided solution satisfies a number of constraints. Another option is to require some sort of semantic equivalence between the two models (e.g. class diagrams that are consistent with the same object diagram). Moreover, tutors need to be able to define different types of levels and link them up to assemble complex games.

Rewards are a major element of learning games allowing users to develop a sense of achievement, show off their new skills, compare themselves against other users, etc. So far, there are two types of rewards in this game, positive reinforcement and achievements. Positive reinforcement is presented in the form of sounds, visual effects, or encouraging texts to give feedback to players whether they are making good or bad actions while playing. Positive reinforcement are intended to improve the self-efficacy of players by keeping them informed of their progressing whether they are heading to the right direction or not so they can decide and continue execute their next actions [17]. Other reward is list of players' achievements. Basically, the list acts like a 'CV' for learners. It inform the names, types, and numbers of levels and learning patterns that they have been completed. Since a learning pattern usually address a concept in software modelling, completing the pattern could be used as base to claim that the learners have aquired the competence–knowledge and skill–for that concept which is rewarding to them [17]. Building learners' competence also means stregthening their intrinsic motivation [18] which could lead to meaningful gaming activity [19].

III. Solution Overview

A a solution, a web-based framework has been developed to address the problems presented in the Problem Analysis section. The framework implements a metamodel-annotation-based approach for defining the concrete syntax of modelling language similar to the approach that has been implemented in Eugenia [20]. In this way, tutors can write different types of annotated metamodels to produce different types of visual modelling languages. Annotated metamodels were then consumed by a model-to-text transformation that generates web-based graphical editors on top of the MxGraph framework (https://jgraph.github.io/mxgraph/).

A modelling language is also created for tutors for defining and linking up different types of levels. We name the models constructed by this modelling language as learning pattern models. The learning pattern models are then consumed by a model-to-text transformation to produced a complete playable game. The web-based framework can host a number of generated games and provides features such as authentication, progress management, learning pattern inventory, model inventory, etc.

Currently, only construction gameplay is supported for levels and the correctness of solutions is assessed using EVL [21] constraints that the game designer has specified for each level. The remaining level types and validation approaches as well as reward mechanisms are under implementation.

Some possible extensions that are planned for the framework are as follows. A fine-grained logging framework that will allow game designers to replay solutions and understand how users interact with the game. Automated model mutation to automatically generate incorrect alternatives in a-type levels. A facility that monitors the progress of learners and adapts the game accordingly (e.g. displays fewer instructions and allows fast learners to skip levels).

IV. Demonstration

In this section, an example is presented to demonstrate the use of the framework. The example is to show the of teaching the concept of substates in UML statechart modelling. In this demonstration, designers are assumed to have proficient knowledge and skills of statechart diagram while learners are assumed already understood the concept of states, transitions, start state, and final state. The following subsections are the order of the statechart from its definition to be fully used in a game play.

A. Define Statechart Metamodel

In order for the framework to support modelling in statechart diagram, designers have to define its metamodel first. The metamodel is written in Emfatic (https://www.eclipse.org/emfatic) and Eugenia-like annotations [20] are used to define its concrete syntax. For example, the definition of Start State derived from Node class is displayed in Fig. 1. Other basic elements of statechart diagram, such as states, transitions, end states, etc., are also defined but not displayed in the figure.

```
abstract class Node extends Entity {
  ref Edge[\\]#source outgoing;
  ref Edge[\\]#target incoming;
}

@node(label="name", dhape="startState", whiteSpace="wrap",
    html="1", fillColor="#000000", width="30", height="30")
class Start extends Node {
}
```

Fig. 1: A definition of Start State derived from Node class using Emfatic and Eugenia-like annotations.

The annotated metamodel then trasformed using Epsilon [22] and EMF (http://www.eclipse.org/modeling/emf/) to generate the Java codes of the metamodel, as the backbone codes for further model operations, and Javascript codes to display the statechart's elements as visual elements in a palette of an MxGraph-based graphical editor.

B. Create Statechart Model

Using the MxGraph-based graphical editor (Fig. 2), designers can now create statechart models. The editor has a pallete on the left side that contains elements of statechart's elements which they can drag and drop into a drawing area on the centre where they can arrange the elements to construct statechart models. The editor also has a property panel on the right side to modify the attributes and appearance of the models. Models that have been created can be saved and loaded again for further operations. The editor also can be used to create models as input/base models to be embedded in learning activities.

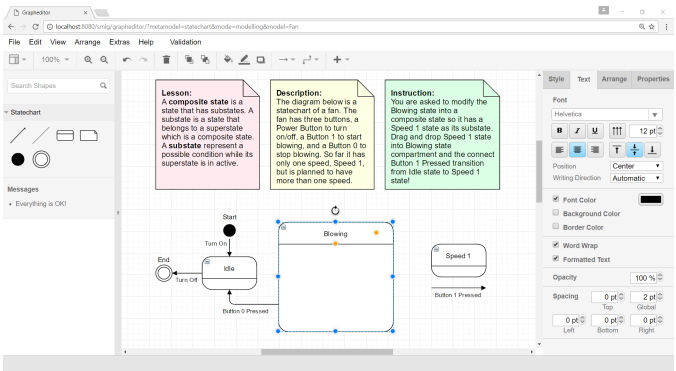


Fig. 2: The MxGraph-based graphical editor to create statechart models.

C. Create Learning Pattern Model

To teach and learn a concept, designers have to design a learning pattern that consists of ordered learning activities. In this example, a learning pattern to learn the concept of substates is created (Fig. 3). The case that is selected is an electrical fan that has two main states, Idle and Blowing. Learners will be asked to modify the Blowing state so it becomes composite state that has several substates that represent different speed of blowing. The learning pattern has three activities, namely One-Speed Fan, Two-Speed Fan, and Tree-Speed Fan. The activities are arranged *per se* to accommodate Flow state [11] so learners can start learning from the easiest activity to the hardest one. The activities are explained in more detail in the next following subsections.

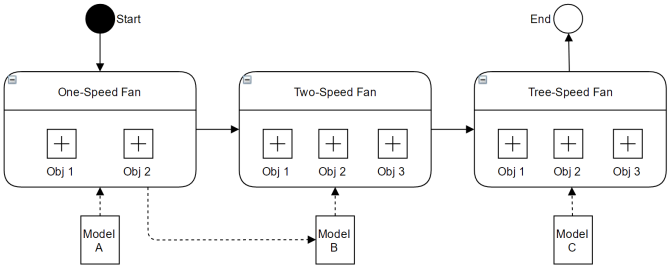


Fig. 3: A learning activity pattern for learning the concept of Substates in state-machine modelling.

Each activity has lesson and instruction properties. Lesson contains explanation about the concepts that are being taught and instruction contains commands or questions that learners need to execute or answer. In the process of satisfying the instruction in each activity, one or more objectives have to be met by learners in order to move to next activity. Also, each activity can consume existing models (Model A, B, and C in Fig. 3) as its base models so learners do not have to create a model from scratch and produce model (Model B in Fig. 3) to be used in its next activity. Each of the models also has a description property to describe itself which is very useful for learners to understand about the model. An example of the lesson, model description, and instruction properties of the One-Speed Fan activity (Fig. 3) is displayed in Fig. 4.

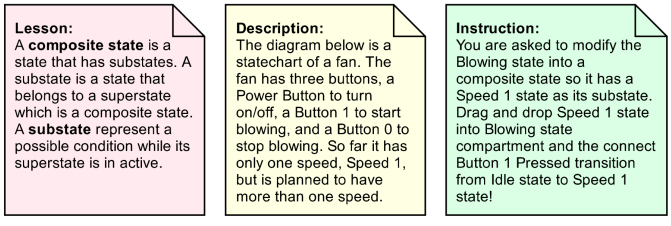
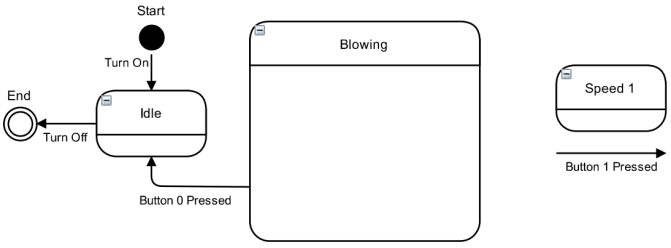


Fig. 4: Lesson, model description, and instruction.

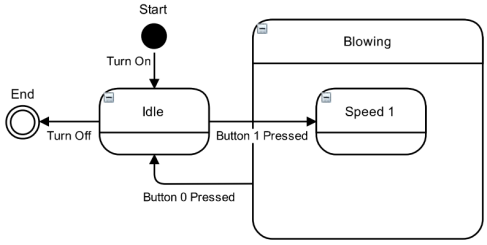
1) One-Speed Fan Activity: In this activity (Fig. 5), learners are introduced to one substate only.The activity start with a base model and learners are required to modify the base model (Fig. 5a) to meet the target model (Fig. 5b). The base model

corresponds to Model A in Fig. 3, which refers to an existing model that already created previously and will be loaded once the activity is executed so leaners do not need to create the model from the start.

The example case in this activity is a fan that has three buttons, a Power Button to turn on/off, a Button 1 to start blowing, and a Button 0 to stop blowing. So far it has only one speed, Speed 1, but is planned to have more than one speed. Learners are asked to modify the Blowing state in Fig. 5a into a composite state through moving the Speed 1 state into the Blowing state compartment as well as to connect the Button 1 Pressed transition from the Idle state to the Speed 1 state. Since in Fig. 3 this activity is designed to have only two objectives, the two objectives are adjusted and defined as follow: Objective 1 "Blowing state contains Speed 1 substate" and Objective 2 "Button 1 Pressed transition connects Idle state to Speed 1 substate".



(a) Base model

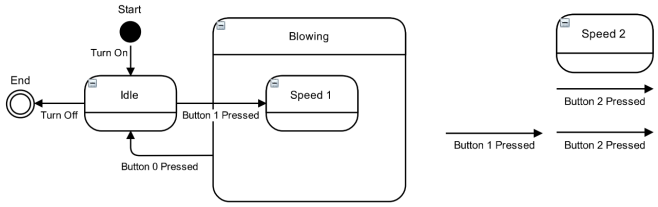


(b) Target model

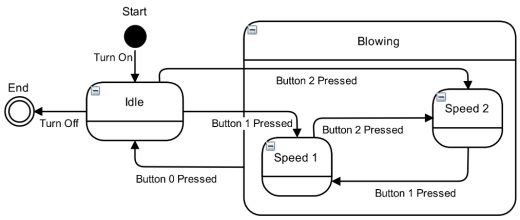
Fig. 5: The One-Speed Fan example.

2) Two-Speed Fan Activity: The Two-Speed Fan activity (Fig. 6) consumes the model that has been produced in the first activity (Model B in Fig. 3). Therefore, any model produced in the previous activity will become the base model for modelling in this activity. Inline to the Flow concept [11], this second activity has to be more challenging. Therefore, the activity (Fig. 6) challenge learners with one additional state and three new transitions. Now the case has changed. The fan has an additional button, Button 2, to support 2-speed blowing. When Button 1 is pressed, the fan blows in speed 1. When Button 2 is pressed, the fan blows in speed 2. Thus, Learners are required modify the Blowing state into a composite state so it has two speed states. The fan can move from the Idle state to the Speed 1 state, from the Idle state to the Speed 2 state, and from the Speed 1 state to the Speed 2 state or *vice versa*.

3) Three-Speed Fan Activity: The Three-Speed Fan activity (Fig. 7) should be more difficult than the second activity. The



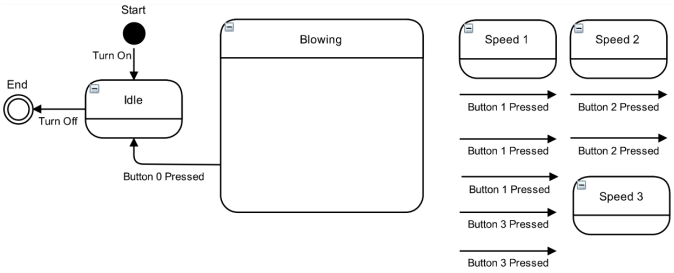
(a) Base model



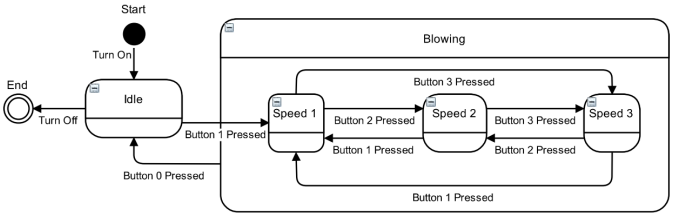
(b) Target model

Fig. 6: The Two-Speed Fan example.

fan now supports 3 speeds of blowing, but it has been modified so it cannot go directly to Speed 2 and Speed 3 without firstly go the state with lower speed. In other words, transition from Idle can only go to Speed 1 for the fan to start blowing–Speed 2 and Speed 3 will not be working if transition comes from Idle state. Thus, starting from the model C as the base model as shown in Fig. 3, learners are required to modify the Blowing state into a composite state so it has 3 speeds of blowing and only allow transition from Idle to Speed 1 and from a speed that is lower from the intended one in order to blow.



(a) Base model



(b) Target model

Fig. 7: The Three-Speed Fan example.

D. Generate Game

After finishing constructing the learning pattern (Fig. 3), designers can now generate a path of levels (or stages) that is usually found in many games. Each generated level

corresponds to an activity defined in the learning pattern. The generation also produces an EVL [21] template for each level for its validation to determine whether the level has been completed, all of its objectives have been met, or not. The EVL template is shown in Fig. 8 which can be extended by designers to write code that fits with the level scenarios and objectives. The number of constraints and operations in the template corresponds to the number of objectives defined in the level's learning pattern activity in Fig. 3. As an example implementation of validation, Fig. 9 shows the EVL code of checking whether Blowing state has already Speed 1 substate as intended by Objective 1 in One-Speed activity.

```
context Statechart {
    constraint obj_1 {
        check:
            self.obj_1()
        message:
            "FAIL: ob_1"
    }
    constraint obj_2 {
        check:
            self.obj_2()
        message:
            "FAIL: obj_2"
    }
}
operation Statechart obj_1(): Boolean {
    return true;
}
operation Statechart obj_2(): Boolean {
    return true;
}
```

Fig. 8: Validation template for objectives in One-Speed Fan activity/level.

```
context Statechart {
    constraint obj_1 {
        check:
            self.obj_1()
        message:
            "FAIL: Blowing state contains Speed 1 substate"
    }
    ...
}
operation Statechart obj_1(): Boolean {
    for (state in State.allInstances.select(state | state.
         name == "Blowing")) {
        if (state.substates.notEmpty() and state.substates.
             select(substate | substate.name == "Speed 1").
             notEmpty()){
            return true;
        }
    }
    return false;
}
...
```

Fig. 9: Validation realisation for Objective 1 in One-Speed Fan activity/level.

E. Play Game

After generating the learning pattern into a path of ordered levels and defining its levels' validation, Learners can choose the path and play its levels as depicted in Fig. 10. When learners choose the first level, an MxGraph-based editor is displayed. Lesson, model description, instruction, objectives, and base model are presented to learners. Learners then can start to modify the base model to reach the target model.

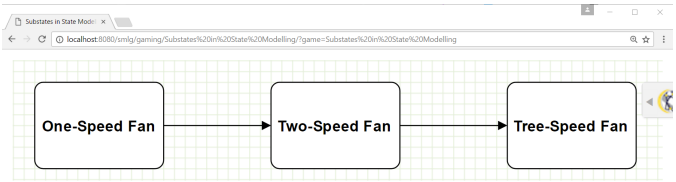


Fig. 10: The path for learning substate concept with its levels.

Every attempt to change the model will trigger an operation to validate the current model using the defined EVL constraints to assess whether the current model has met the current level's objectives. If not, error messages are displayed to learners indicating the objectives that have not been satisfied. For example, in Fig. 11, the Speed 1 substate has not been put into the Blowing state even though the Button 1 Pressed transition has connected the Idle state to the Speed 1 substate. If all objectives have been fulfilled, learners have completed the level. A message that congratulate the learners is displayed to give positive reinforcement. Learners then are brought back to the learning path where they can choose the next level to play.

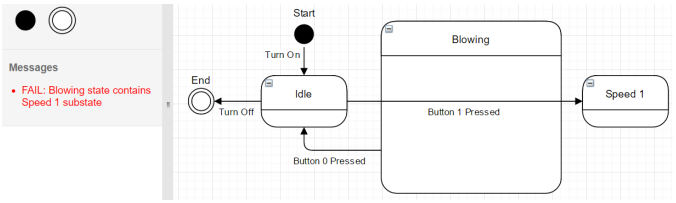


Fig. 11: A message is displayed to learners indicating the objective that has not been fulfilled.

V. Evaluation Plans

Two forms of assessment have been planned to evaluate the framework. The first assessment is to measure the effectiveness of modelling games vs. class-based lecturing using controlled experiments involving undergraduate and postgraduate students. Subjects will be grouped into two groups, one is experimental group and the other one is controlled group. While the controlled group will only learns from attending class-based lecturing, the other group will also learns using games. Both will be tested with relevant problems before and after treatment to measure the gap of their improvement and the gap between the two group is effect of the games. Even though this evaluation is feasible since adequate number of software engineering students are available, challenges still exist. The quality of the class-based lecturing, the problems given in the tests, and the games has to be consistent, ensuring that they carefully designed to address the same educational objectives. The other challenge is to have the two groups of subjects have a balance quality and distribution.

The second assessment is to measure on the development effort needed to develop a complete game for a non-trivial modelling language and the savings realised using the model-driven approach. The assessment will be tested on developers that has considerable background in developing games, which also imply a challenge since it's difficult to get developers that have such qualification but also willingly participate as subjects. The measures will be on time used to complete the game and ratio between lines of code written and lines of code generated. Subjective feedback from the developers will also be useful to describe the quality of the framework.

VI. Related Works

There are not many studies that investigate the application of gameful approach in software modelling. So far, only four studies are identified closely relevant to our work. Stikkolorum et al. [7] develop a game that is intended to teach software design principles, such as cohesion, coupling, information hiding, and modularity in object-oriented software design. Groenewegen et al. [8] apply gamification to improve stake-holders' understanding of their enterprise architecture models as well as to validate them. In the domain of information security modelling, Ionita et al.[9] develop a socio-technical modelling language (TREsPASS) that maps information on security-related concepts toward tangible representation. In the context of activity diagram learning, Richardsen [10] develops a game, whose behaviours are controlled through an UML activity diagram. Each of the studies addresses different topics in software modelling using different approaches and game elements. This fact challenges us to develop a more generic approach in addressing software modelling learning, so that tutors do not need to develop individual games from scratch only to address certain topics. Moreover, the common drawbacks of the studies are that most of them did not consider the pedagogical aspect of their solution as well as their validation was weak in sample size as well as the lack of discussion of internal validity. Nevertheless, all of the studies reported that their gamified approaches have a positive effect– it is motivating and engaging users in varying degrees, which confirms that gamification has a positive impact on motivation.

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