Configurable Framework for Smart Serious Game Analytics

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Abstract

Serious game has been introduced as an interactive educational tool for teaching and learning processes. It incorporates non-entertainment elements into an interactive game environment. Although serious game offers various benefits to support teaching and learning in a variety of contexts, measuring the learner's skills and knowledge improvement is difficult. Two main problems are: 1) how to understand the learner's skill and performance improvement, and 2) how to capture and analyse the data. This work aims to tackle the second problem by designing a flexible serious game analytics framework. It focuses on identifying the relevant data to evaluate learner's skills and knowledge improvement for a specific intended learning outcome, as well as, gathering this data in a serious game framework that can be configured based on the intended learning outcomes of the game. Comprehensive literature reviews and field study, including observations and semi-structured interviews, were conducted to consider different gameplay data and identify the necessary gameplay data for a particular learning outcome. Based on the findings, a serious game framework is developed. This framework would be implemented as a configurable setting for the smart serious game analytics engine.

Keywords
Serious game, serious game framework, configurable, analytics engine, evaluate learner

1. Introduction

Serious game has emerged as an alternative education tool that engages the learners by balancing the entertainment and non-entertainment elements (Liu, Alexandrova, & Nakajima, 2011; Ma, Oikonomou, & Jain, 2011). It is used to teach specific knowledge and skills such as computer programming (Coelho, Kato, Xavier, & Gonçalves, 2011; Muratet, Torguet, Jessel, & Viallet, 2009) and supply chain management (William, Rahim, Souza, Nugroho, & Fredericco, 2018). These knowledge and skills are infused into the game environment while maintaining the entertainment factors that would keep the learners engaged and interacted with the game. It would encourage voluntary learning through engagement and interaction with information, tools, materials, other learners, as well as with the lecturer/facilitator within the game (Kim, Park, & Baek, 2009).

Numerous studies have revealed the benefits of using serious game as an alternative education tool (Ma, Oikonomou, & Jain, 2011). The benefits include boosting engagement, motivation, and self-monitoring (Ma, Oikonomou, & Jain, 2011; Rieber, 1996; Knight, et al., 2010; Kumar, 2000) and enhancing formative assessments (Handfield-Jones, Nasmith, Steinert, & Lawn, 1993; Delacruz, 2011; Wang, 2008; William L. A., 2019). The serious game would encourage active participation and interaction from the leaners that would eventually increase the learner's understanding of specific knowledge and skills (Hou, 2015).

Despite numerous benefits of a serious game proposed by academia and experts, evaluating the serious game effectiveness and learner's improvement of knowledge and skills are still difficult. Two main problems are: 1) how to

understand the learner's skill and performance improvement, and 2) how to capture and analyse the data (i.e. data from gameplay session or other data). These questions need to be answered and incorporated in the game from the beginning (i.e. game design stage) and not only in the game evaluation stage. To date, there are limited engines that can help to evaluate the serious game's effectiveness on improving the learner's skills and performance. Most of the available engines merely focus on improving the game entertainment experience rather than enhancing the learner's skills and understanding. Without these evaluation mechanisms, it would be impossible to determine what actions performed in the serious games constitute newly acquired skills, ability and knowledge and to determine the "real learning" that the students get from these serious game (i.e. skill improvement).

1.1 Objectives

This work aims to solve the second problem to identify, capture and analyse essential game data and turn it into actionable insights to measure the serious game effectiveness and learner's improvement of knowledge and skills. It focuses on developing a configurable serious game design framework to identify critical gameplay data (i.e. learner's in-game actions and decisions) based on specific intended learning outcomes of a particular subject or course. Recognising that not all the gameplay data is useful (Loh, Sheng, & Ifenthaler, 2015), this framework is developed to include flexibility to capture the essential data and remove the irrelevant data for different learning outcomes to evaluate learner's skills and knowledge improvement. Other serious game design factors such as user interactivity and user interface would not be covered.

2. Literature Review

2.1 Serious Game Design Framework

Best practices and frameworks in serious design have been introduced in the literature (Van Staalduinen & de Freitas, 2011). These best practices and frameworks combine game design and instructional design components to balance the entertainment and non-entertainment components in serious game. It includes the Game Object Model (Amory & Seagram, 2003; Amory, 2007), the Experiential Gaming Model (Kiili, 2005a; Kiili, 2005b; Kiili, 2005c), the Four-Dimensional Framework (De Freitas & Oliver, 2006; De Freitas & Jarvis, 2009), and the Game-based Learning Framework (Van Staalduinen & de Freitas, 2011).

Game Object Model (GOM)

Game object model (GOM) is derived from the object-oriented programming concept to design a dialectic relationship between the pedagogy elements and game elements (Amory & Seagram, 2003; Amory, 2007). Pedagogy elements, such as critical thinking, discovery, goal formation, goal completion, competition and practice, are combined with game elements that can implement the pedagogy elements in a game, such as a story, plot, and interaction. The pedagogy elements are referred to as the components that promote educational objectives. In contrast, the game elements are referred to the components that implement these educational objectives within different spaces in-game environment. Each component can be an independent component or part of other components. This model supports the development of educational computer games where educational games should be the appropriate, explorative, dynamic and engaging environment.

Experiential Gaming Model

Experiential gaming model was introduced in 2005 to describe the relationship between the gameplay with the experiential learning to facilitate flow experience (Kiili, 2005a; Kiili, 2005b; Kiili, 2005c). It aims to help the game designer to understand the in-game learning mechanism by integrating pedagogy elements into the design and distinguishes the factors for enjoyable games. It uses flow theory which is defined as a total engagement in the game that motives the players to win the game by achieving new skills and understanding new concepts voluntarily (Kiili, 2006). Experimental gaming model involves two cycles, namely: gaming cycle and design cycle. The gaming cycle provides the description and learning process in the game, while the design cycle provides the phases of game design as a guideline in the game designing process.

Four-Dimensional Framework

This framework introduces four dimensions in game design, namely: learning specification, pedagogy, representation and context. These dimensions involve in learning processes and in need of consideration for game selection (De Freitas & Oliver, 2006; De Freitas & Jarvis, 2009). It helps to form an iterative process to evaluate the potential of using game-based learning in the teaching environment. The summary of the four dimensions is in Table 1.

Table 1. Summary of four-dimensional framework

Dimension	Description	Examples of consideration
Learning specification	Learning model and profiling.	Learner profile, Pathway, Learning background, and Group profile.
Pedagogy	Roles of pedagogy approaches for supporting learning.	Learning models used, and Approaches took.
Representation	The representation of the game itself (i.e. engagement and interaction in the game).	Level of fidelity, Interactivity, and Immersion.
Context	The context where learning takes place.	Class-room based, Outdoors, Access to equipment, and Technical support.

Game-based Learning Framework

Game-based learning framework explores the relationship between game elements and expected learning outcome (Van Staalduinen & de Freitas, 2011). It includes three components, namely: learning, instruction and assessment. The summary of factors for each component is shown in Table 2. This framework has been widely adapted for game design, such as board game design as illustrated in Figure 1 (William, Rahim, Souza, Nugroho, & Fredericco, 2018; William, Rahim, Wu, & Souza, 2019).

Table 2. Summary of game-based learning framework

Component	Factors
Learning	Learning objectives, clear player goals, and learning content.
Instruction	User behaviour, user feedback, user engagement, and user learning,
Assessment	Debriefing and system feedback.

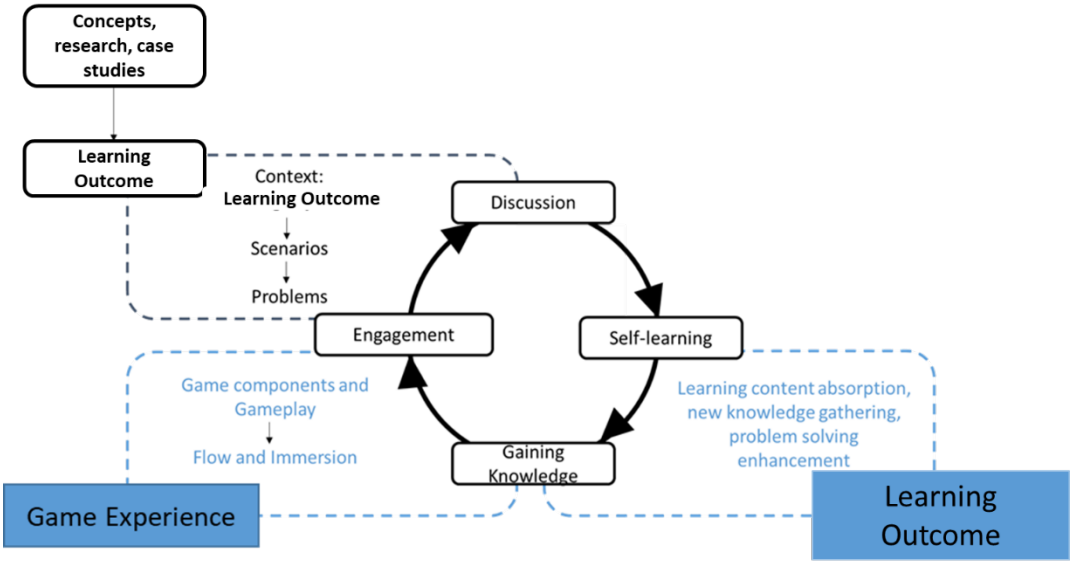

Figure 1: Game design framework (William, Rahim, Souza, Nugroho, & Fredericco, 2018; William, Rahim, Wu, & Souza, 2019)

2.2 Serious Game Analytics

Serious game analytics is different from game analytics. Game analytics aims to improve the gameplay to entertain the customers and gain more profit. These analytics include correct game balance, better game design, detect game problems, and identify new opportunities for additional revenues (Canossa, Seif El-Nasr, & Drachen, 2013; Thawonmas & Iizuka, 2008; Williams, Yee, & Caplan, 2008). In contrast, serious game analytics focus on the learner's skills and performance improvement. The purpose of serious game analytics are two folds: 1) obtain valuable actionable insights to better the game or learning design, and 2) improve skills and performance of the learners to better measure the game's effectiveness (Loh, Sheng, & Ifenthaler, 2015). The summary of differences between game analytics and serious game analytics is shown in Table 3.

Table 3. Summary of differences between game analytics and serious game analytics

	Game Analytics	Serious Game Analytics
Purposes	1. improve gameplay and make the game more enjoyable, 2. improve the game design, and 3. increase revenue (i.e. in-game purchases).	1. obtain valuable insights to better the game or learning design, and 2. enhance the learner's skills and performance.
Sample of metrics	hours of continuous play, frequency of play, in-game/in-app purchases.	the time required to complete the lesson or the game, time of access, number of mistakes made during the game session.

3. Methods

Comprehensive literature review on serious game design and serious game analytics were performed to analyse different gameplay data. An exploratory field study was then conducted to identify additional factors to be considered for serious game analytics. The exploratory field study includes classroom observations and semi-structured interviews. The classroom observations would focus on learner's perspective on three main factors, namely: 1) challenges to learn the programming language, 2) interaction between learners in the classroom and 3) acceptance to serious game introduced in class. While semi-structured interviews focus on lecturer perspective on gamification,

serious game and serious game analytics for a particular programming subject. List of questions in the semi-structured interviews is shown in Table 4.

Table 4. List of questions for the semi-structured interview

No	Item	Category
1	What is your preferred teaching style when teaching a programming class?	Teaching style
2	Are there any topics that are particularly difficult to teach, is there a way/method you use to teach it better to your class?	Teaching style
3	Do you have any experience with serious games that teach programming languages? If not, what are your thoughts about serious games?	Gamification/serious game acceptance/experience
4	What are your opinions on using serious games that teach programming languages to teach a module?	Gamification/serious game acceptance/experience
5	Would you implement a serious game that teaches programming languages into your teaching plan if given a choice?	Gamification/serious game acceptance/experience
6	What information or insight you'd like to see on a dashboard for evaluating the students?	Serious game analytics
7	What are some methods you use to evaluate whether if a student has understood the topic?	Serious game analytics

4. Data Collection

We conducted 8 observation sessions for one programming class in Temasek Polytechnic from October 2019 to December 2019. The class consisted of 26 learners in their Year 2. At the beginning of the subject, the learners were introduced to a serious game and were given a fixed time to complete the game. The learners needed to submit a proof of completion to get the mark for the subject. During the observation sessions, we noted down the learner's interaction with other learners and the lecturer, topics that they are discussing in class and also their perspective about the serious game introduced in class.

We conducted six semi-structured interviews with six lecturers in Temasek Polytechnic in July 2020. All of the lecturers were teaching programming classes or have taught programming classes previously. Each session was recorded and would last between 30 to 60 minutes. At least two interviewers were present for each session. After the interview session, a report detailing the answers for each interview question was written by the interviewers.

5. Results and Discussion

Based on these literature review, observations and semi-structured interviews, we identify seven important components for serious game analytics as summarised in Table 5. Relevant gameplay data that is required for the serious game analytics is described in component 5. Based on these components, we propose a serious game analytics framework to gather the required game data for analytics. The framework allows the lecturers to configure the setting to accommodate different learning outcomes and assessment points needed for each concept and skill, as illustrated in Figure 2. The framework has two primary tools, namely: the serious game engine and the analytics engine. The configuration would be saved in a shared database that can be accessed by both the serious game and analytics engine as defined in the architecture diagram in Figure 3. Lecturers would be able to change the configuration from the web application backend and view the serious game analytics from the web application front end.

Table 5. Essential components for serious game analytics

No	Component	Description	Source(s)
1	Learning outcomes	Learning outcomes are the concepts, skills and knowledge that learner should acquire by the end of the game. It is determined by the lecturer for each topic or sub-topic within a particular subject.	Literature review, semi-structured interview
2	Assessment points	Assessment points are measurements to evaluate the improvement of learner's skills and knowledge by playing the game. It can be broken down into questions for each topic and sub-topic. It should be aligned with the learning outcomes of the subject. For each topic or sub-topic, the number of assessment points can be varied.	Literature review, semi-structured interview
3	Game scenarios	Game scenarios are gameplay of the serious game that would combine the pedagogy aspects (i.e. learning outcomes, assessment points) and entertainment elements (i.e. fantasy, challenge, playability). It should incorporate the learning outcomes and assessment points determined by the lecturers in an engaging and immersive game environment. It would make the learners invest their time to play the game and learn about new concepts, skills and knowledge voluntarily.	Literature review, semi-structured interview, observation
4	Events in-game	Events in-game are carefully planned to ensure the learning happened. Instant feedback in-game would help the learners to understand their mistakes and advance their understanding of certain concepts, skills and knowledge.	Literature review, semi-structured interview, observation
5	Game data	Based on the events in-game, game data is collected to analyse the improvement of learner's skills and knowledge. The required game data includes: - amount of time to clear a level, - amount of time to answer questions or tasks related to specific assessment points, - number of attempts the learners tried to clear a level, - number of hints the learners need to clear a level, - number of levels that the learners have cleared, and - feedback from the learners (i.e. difficulties that the learners encountered during the game).	Literature review, semi-structured interview
6	Serious game analytics	Based on the game data collected, serious game analytics would be developed to analyse the improvement of learner's skills and knowledge. A dashboard containing data analytics would be developed. The information/insights in the dashboard include: - a graph for learner's performance or KPI, - a chart for learner's time spent in-game, - a graph to analyse the group of learners that would need additional help from the lecturer, and - a graph or table for learner's feedback.	Literature review, semi-structured interview
7	Configurable setting	Different subjects, topics and sub-topics have different learning outcomes and assessment points. The serious game analytics framework should be able to accommodate these changes smoothly.	Semi-structured interview

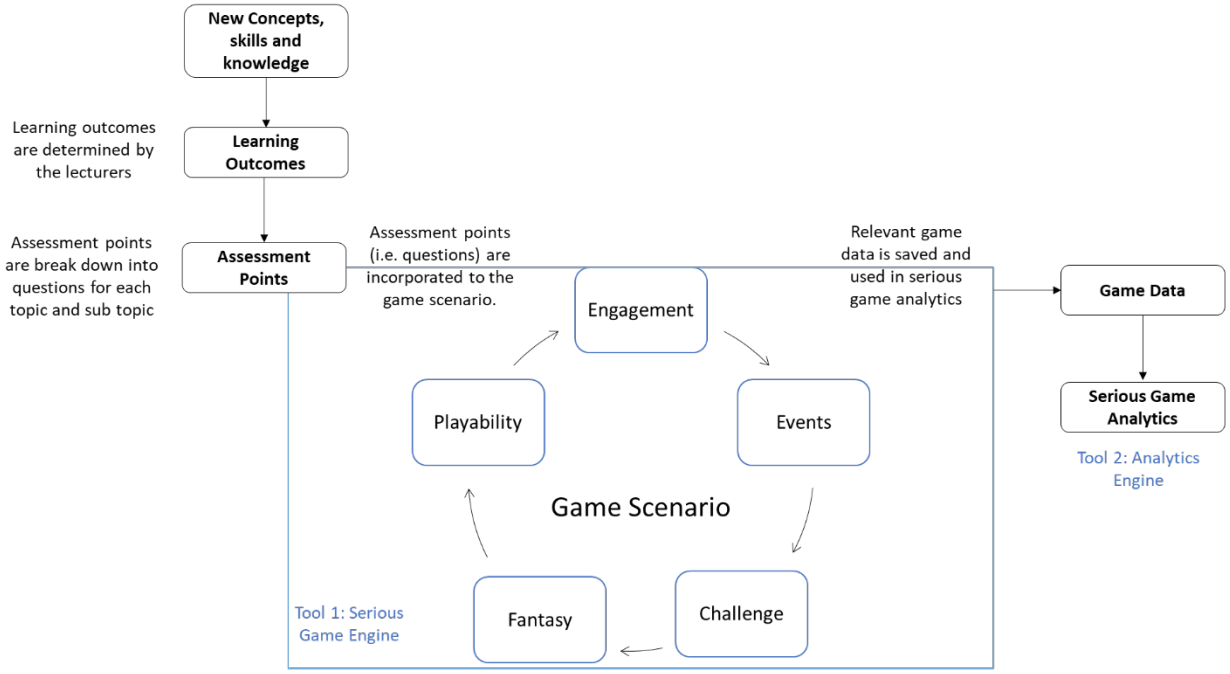

Figure 2: Serious game analytics framework

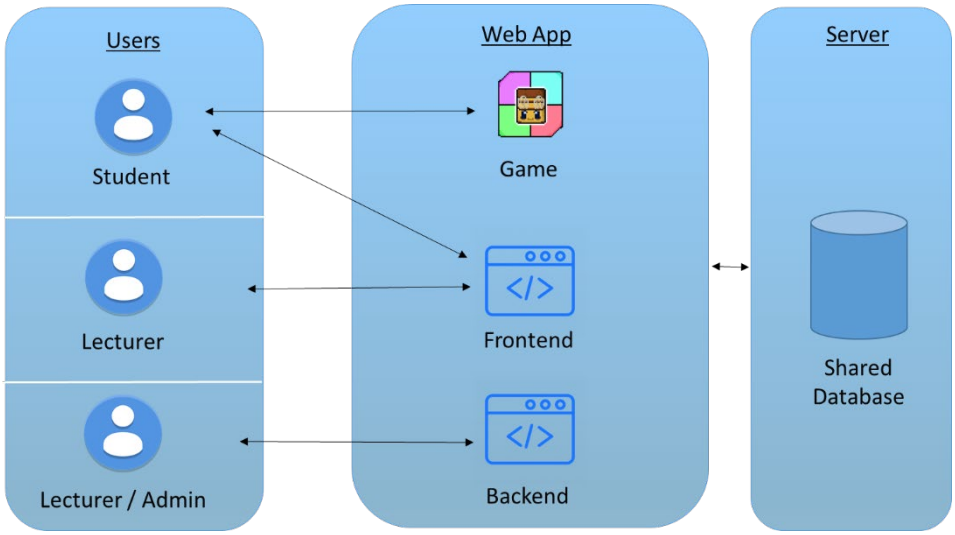

Figure 3: Architecture diagram of the serious game analytics framework

6. Conclusion

This paper focuses on designing a serious game analytics framework to identify relevant data and analyse the data to evaluate learner's skills and knowledge improvement for a specific intended learning outcome for a particular programming subject. Comprehensive literature review in serious game design framework and serious game analytics, as well as field study that includes observations and semi-structured interviews, was conducted to consider different components and gameplay for the framework. Based on the findings in the literature review and field study, we propose a serious game analytics framework that consists of two engines, namely: serious game engine and analytics engine. To enable flexibility in the configuration, the game and analytics configurations (i.e. assessment points, gameplay data, analytics results) are saved in a shared database that can be accessed by the game engine and analytics engine.

To validate and enhance our proposed serious game analytics framework, we see two possible extensions that we would like to study in the near future. First, we would like to implement the two engines based on our framework to a specific programming subject such as Introduction to Python. The implementation will help us to validate if the configurable framework can capture both gameplay data and analyse the data to identify the learner's skills and knowledge improvement. Second, we would like to work closely with the lecturers to determine additional information or insights that they would need to analyse the learner's improvement. It would further enhance the analytics capabilities of the framework.

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