ChemistLab: An Educational Game with Learning Analytics Dashboard

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***Abstract*— Educational games are games explicitly designed with educational purposes and aims to balance learning and playing. These educational games help people to learn and improve as they play. However, there is a lack of gameplay monitoring process whereby the real-time information of game progress is not being reflected. Most of the existing educational games do not consolidate with learning analytics dashboards which leads to no visualization of gameplay information and inadequate gameplay analysis. When players have information on how to improve their performance, they will be encouraged to revisit the game. Hence, an educational game with learning analytics dashboard, *ChemistLab*, is developed for learners to learn chemistry. The dashboard will visualize the performance and skills changes overtime which reflect the players' learning patterns and strategies used to improve their performance for better learning. The learning content of the game is extracted from the Malaysia Upper Secondary Education (Form 4) Chemistry syllabus. The expected output of the game is to allow users to observe their gameplay performance through the dashboard and gaining new knowledge through the game with the achievement of learning objectives.**

Keywords: Educational game, Gaming analytics, Learning analytics, Analytics dashboard, Chemistry

I. INTRODUCTION

The main purpose of educational games is aimed to balance learning and playing at the same time [1]. Educational games enable the users to learn quicker and easier in a much more relaxed state [2]. For users to benefit from an educational game, they are encouraged to play the game more often. However, educational games are designed in a way that after the user finished playing the game, the user will not reinitiate the game. This is due to the reasons of; the game tactics have been figured to solve the game or there is no learning analytics dashboard to visualize the information to the users. Thus, by incorporating learning analytics dashboards in the educational games, users can oversee their strengths and weaknesses in a particular part of the entire game process. [3] mentioned that learning analytics provides opportunities to the users to reflect about their learning.

There are three main challenges in the existing works which we aim to address in this proposed work. Firstly, most of the educational games has no learning analytics component and dashboard. Subsequently, the gameplay analysis can't be visualized to the users to interact with and lastly, there is no visualization provided on gameplay analysis. [4] stated that if visualization is presented in a meaningful way, the users are capable of processing large amounts of data. To improve the educational objectives achievement of the users, real-time analysis is needed to be implemented in the educational games. To address the problems stated as above, we aim to achieve the following objectives in our proposed work: 1) To design and develop an educational game with a game learning analytics dashboard, 2) To perform learning analytics during educational gameplay and 3) To visualize the learning analytics in a dashboard.

II. LITERATURE REVIEW

A. Educational Games/Serious Games(SG)

Educational games, which are also known as Serious Games (SG), are solely designed for educational purposes, for instance, to teach a subject, to spread awareness, to improve a skill, etc. [5] stated that the goal of educational games is to allow players to learn unconsciously while playing. According to [6], the authors developed a module called Malaysia Kimia (Chemistry) Digital Game, MyKimDG to assist students in learning the salt-related topics and in achieving the desired learning goals. The game activities are aimed to train the student's skill on collaborative and discovery learning. The module was proven to assist in producing higher content achievements and more effective than the conventional teaching method.

B. Learning Analytics Dashboard (LAD)

LAD enabled the stakeholders to monitor their progress, to reflect their learning or teaching pattern, and to keep track of their scores for gaming-wise dashboards. According to [7], most of the game-based dashboards used badges which intending to motivate users in engaging in learning. The badges are indicators that show the user's level of achievement in certain rounds of gameplay. [8] stated that digital learning game is a substantial tool to promote learning by engaging students with an unorthodox game environment. The proposed game is called Decimal Point, a game that teaches decimal numbers and operations to middle-school students. The authors investigated how well and duration for the student mastered the in-game skills, and whether students continued in practicing after mastery.

Table 1 shows the comparison between existing systems and the proposed system, *ChemistLab.*

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TABLE I. COMPARISON BETWEEN EXISTING SYSTEMS

Functionalities	*Dashboard*			*Game*			*Proposed System*
	Kibana[9]	Grafana[10]	Khan's Academy Learning Dashboard [11]	COVID: The Outbreak[12]	ChemCaper [13]	Idle Evolution [14]	ChemistLab
Filter Data	✓	✓					✓
Statistics	✓	✓	✓				✓
Achievements			✓	✓	✓	✓	✓
Challenges				✓	✓	✓	✓
Levels/Stages				✓	✓	✓	✓
Progress Tracker				✓	✓	✓	✓
Scoring				✓	✓	✓	✓

As presented in [11], it is a learning dashboard which allows the user to learn the subject they preferred. The learning materials are limited, and the difficulties of the learning content are tailored for beginners only. To improve this said limitation, various levels of difficulty on the learning materials is provided by *ChemistLab.* [12] is a chemistry-based game focused on the user's gameplay experience whereby the achievement of the learning outcomes of the user is not measured. For *ChemistLab*, we will overcome this by selectively extract the learning objectives and distribute across each mini stages while also retaining the game-world exploration experience. [13] focused on using the dashboard to assist a mission. To improve the gameplay experience in *ChemistLab*, a comparison of performance between current user versus average users will be implemented in the dashboard.

III. PROPOSED SOLUTION

Our proposed system aims to improve the main limitation of the existing systems. We have extracted and collected the learning objectives from Malaysia Upper Secondary Education (Form 4) Chemistry Textbook, which is Chapter 2 and Chapter 4 respectively. After that, we gathered required functionalities from stakeholders and design corresponding UML diagrams prior to implementation. The potential users for *ChemistLab* are secondary school students, chemistry enthusiastic or non-chemistry learners. The main modules proposed are as follows:

- User management – Allows the user to login and register to ChemistLab.
- Game management – Allows the user to initiate the game, play the desired game stage and view achievement board.
- Dashboard management – Allows the user to manage the dashboard, view the main dashboard, progress tracker and leaderboard.

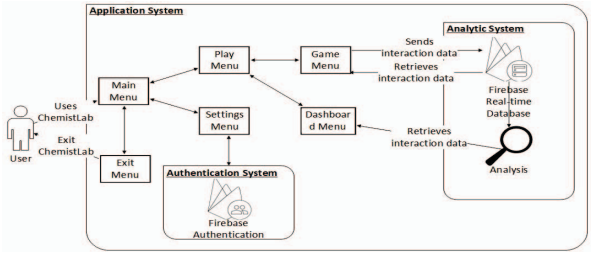

Figure 1. Overall Flow of ChemistLab

Fig. 1 demonstrates the overall flow of the system. The game and UI/UX design approach are inspired by Sonic Generations, League of Legends and Angry Birds. The game logic approach is novel and unique to ChemistLab, where the user would have to solve three mini stages beforehand to obtain the scroll. "Question Wall" is the blockage at the end of each mini stage that prohibit the player character to proceed into the next region. Upon successful attempt on the question, the wall will explode immediately, and the player character can proceed. The user can search for tips scattered across the stage or Ask For Help (AFH), a premium tip that provides the answer directly to the user and can be purchased using scores in the Store. Real-time statistics can be accessed via home dashboard. Leaderboard dashboard calculates interaction data and displays it as a radar chart and a filterable score comparison list. Lastly, all in-game interaction data that can be tracked are accessible within progress tracker dashboard.

IV. IMPLEMENTATION RESULTS

Based on the proposed solution, we have used Unreal Engine version 4.25 to design the system, Firebase Real-time Database for database design and learning data capturing model, while Firebase Authentication for user authentication. The data for learning analytics is directly retrieved in real-time basis, during or after the gameplay session and saved into the database concurrently. Fig. 2 and Fig. 3 are sample UIs of the main modules in *ChemistLab*.

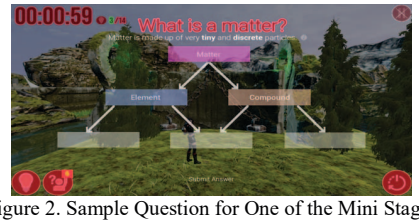

Figure 2. Sample Question for One of the Mini Stages

Figure 3. Home Dashboard

V. User Testing And Evaluation

Testing which has been performed for *ChemistLab* includes alpha, beta, and black box testing. There are a total of 12 beta-testers and the age range is from 16-22 years old. The testing phase had been carried out over the course of a week. The beta-testers are divided into three main categories, which are Science stream, Commerce stream and Information Technology (IT) stream. Beta-testers of Science and IT streams can recall certain knowledge of chemistry. We collected feedbacks through Google Forms and findings show that some of the testers are required to refer to the chemistry textbook while playing the game, while the others can answer the questions directly. Beta-testers under Commerce stream suggested that tips discovered can be viewed in the current game UI, so that they are not required to refer to the tips again. They ranked this game as requiring much effort to digest the tips. Moving on to the dashboard, some of the beta-testers commented that the leaderboard encourages them to be competitive. The program is redistributed again for testing after revision based on the users' feedback and suggestions.

A. Learning Effectiveness

The interaction data which are considered for quantitative analysis includes Tips Found, AFH and Success Attempts. The aim of quantitative analysis is to identify how effective are these assistance tools on the user acquiring successful attempts during the learning process. Success attempts is chosen as the target metric because it will only be obtained if the user understands the questions and at the same time, the learning objectives of that stage will be achieved as well. These interaction data are extracted into .csv file and imported into Jupyter Notebook.

In this quantitative analysis, prediction on the user's performance will not be carried out due to the data constraints. By applying data mining approach, the dataset will be preprocessed, which includes validating missing values and treating outlier values. For this study, correlation heatmap is used to visualize the relationships between these three metrics. Based on Fig. 4, Tips Found is more effective in assisting the user as it has higher correlation towards Success Attempts compared to AFH.

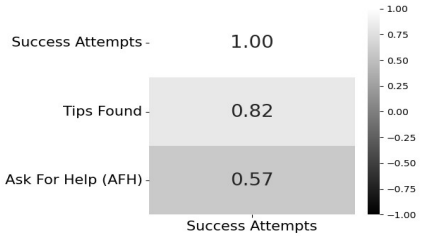

Figure 4. Correlation Heatmap

VI. Conclusion

ChemistLab provides a new way of learning chemistry which allows users to learn by playing the educational game and interact with learning analytics dashboard. For future enhancement, we would need to evaluate how effective *ChemistLab* is for the users by conducting experiment on control and treatment group. With sufficient data, prediction on learning outcomes and other factors of the user can be performed by feeding data into the classification models. Besides, pre-test and post-test assessment are crucial in performing learning analytics, so that the curve of learning effectiveness can be observed thoroughly. The element of pedagogy is required to ensure the users can learn chemistry effectively as the current game environment and the tips are not closely related to the subject itself. The hints feature can be improved by providing clues instead of full answer. Furthermore, more learning content and game-based microlearning approach will be included in *ChemistLab*, so that the users have more topics to explore and learn.

Acknowledgment

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