

A Mobile Driving Simulator to Improve Driving Experience for Novice and Learner Drivers

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Abstract—Statistics show that novice and learner drivers have a higher crash risk and lower passing rate for driving tests compared to experienced drivers, posing a risk to road safety. Therefore, we propose a mobile driving simulator game that is designed to provide an alternative driver training solution for novice and learner drivers to improve their driving experiences and prepare for the driving test. This game focuses on promoting safe driving by providing a driver training platform through smartphones, with high portability and functionality. The game consists of three modes - Tutorial, Free Driving, and Driving Test Mode. The Tutorial Mode offers driver training tutorials to teach and remind drivers of their driving knowledge. The Free Driving Mode provides an authentic Hong Kong street view to enhance drivers' recognition of roads in Hong Kong. The Driving Test Mode offers a simulated driving test for learner drivers to practice for their driving test. The game features a high-quality and authentic map of Hong Kong, with street views, buildings, and road objects built according to real-life situations in Ho Man Tin. Players can explore the detailed map while practicing driving with the game.

Keywords—*gamification, serious game, edutainment, driving simulation, mobile game.*

I. INTRODUCTION

The crash rate of novice drivers is significantly higher than experienced drivers. Novice drivers in the first twelve months of a license are 2.7 times more likely to be involved in a casualty accident than standard license holders [1]. The passing rate of private car driving tests for learner drivers in Hong Kong is low nowadays. The passing rate of private car combined driving tests is only 33% in 2021 [2]. Lack of driving experience is the main cause of these issues. Drivers who lack experience have less ability to detect hazards including discovering, recognizing, and reacting against potentially dangerous situations in traffic. Learning to drive demands a lot of practice. Inexperienced drivers need more practice for developing expertise in driving [3].

With the widespread availability of smartphones and the rapid development of mobile application platforms, it is now possible to develop a low-entry-level solution that takes advantage of these trends. By leveraging the high penetration rate and portability of smartphones, we propose a mobile application that allows users to revise road usage rules in Hong Kong and practice hazard perception skills. Learner

drivers can also use the application to revise driving test routes and prepare for their driving test.

This paper proposes a mobile application as a cost-effective and portable solution to improve the driving experience of novice and learner drivers. These groups lack the necessary experience to handle real-world traffic conditions, increasing the risk of accidents compared to experienced drivers. The objective is to offer a functional platform that enhances driving attitudes and promotes anticipatory driving, contributing to the establishment of a smart and safe city. The app allows users to prepare for their driving test anytime and anywhere by promoting anticipatory driving using smartphones. Additionally, the application can aid learner drivers in learning basic driving techniques by providing a virtual driving test to memorize test routes and street signs. The aim is to align with the Road Safety Council's vision of achieving "Zero Accidents on the Road, Hong Kong's Goal."

The paper is structured as follows. Section II. is a Literature Review that discusses the components of driving skills and the problem of drivers with inexperienced driving skills. Gamification on driving is described in detail, and various driver training solutions are discussed and critiqued. Section III. outlines the design of our proposed driving simulator app and its major components. Section IV presents the evaluation results of the game. Section V. concludes with a discussion of the merits and limitations of the app. Possible future works are proposed at the end.

II. LITERATURE REVIEW

A. Problem Analysis

Insufficient Driving Skills on Novice and Learner Drivers. Novice drivers and learner drivers both are drivers with insufficient driving experience. They bring higher on-road risk compared to experienced drivers. A low-risk on-road behavior requires three components: (1) the acquisition of necessary skills; (2) the ability to apply these skills efficiently and effectively when operating on the road and in traffic; and (3) the willingness or motivation to apply these skills when operating on the road and in traffic [1].

Experienced drivers exhibit different levels of skilled performance compared to novice drivers. Novice drivers may encounter challenges when it comes to assessing gap

clearance and closure speeds, have a narrower scanning range, and obtain less information from peripheral vision, among other things. [1]. Novice drivers with insufficient skills tend to have poorer performance on driving tasks, which in turn poses a higher risk to urban safety.

Learner drivers, like novice drivers, may have inadequate skills during the pre-license period. The performance levels of both groups may not satisfy the demands of Hong Kong's heavy traffic system. Therefore, it is necessary to enhance their driving skills to match the unique road usage situation in Hong Kong.

Improvement of Driving Skills. Driving skills can be broadly classified into two categories: higher-order driving skills (HODS) and vehicle handling skills. Inexperienced drivers tend to overlook the significance of HODS, which are crucial for safe driving. HODS encompass skills related to situational awareness, visual search, hazard anticipation, and risk management, as well as the ability to self-evaluate one's driving performance and gain insight into one's driving behavior [5].

Vehicle handling skills can be mastered in just a few hours, whereas higher-order driving skills require a more extended period of practice and experience to develop [3]. To improve driving performance efficiently and effectively, it is crucial to focus on enhancing higher-order skills.

For inexperienced drivers, higher-order skill training can provide valuable instruction in on-road driving, hazard perception, risky driving behavior, and driver confidence levels. Drivers who receive higher-order skill training have shown significant improvement in visual search and composite driving measures. Additionally, they demonstrate safer attitudes towards close following and dangerous overtaking, while also experiencing a decrease in driving-related confidence. On the other hand, drivers who only receive vehicle handling skill training do not show any improvement in hazard perception attitudes or driver confidence [5].

As novice drivers gain more experience, they tend to have higher detection rates and shorter reaction times [10]. However, this process takes time, and inexperienced drivers pose a risk to city safety during the early stages of their driving career. Novice drivers have the highest accident frequency in the first year after obtaining their license [6].

To mitigate these risks, novice drivers should improve their driving skills as soon as possible, while learner drivers should also strive to acquire sufficient driving skills before obtaining their licenses. Properly chosen driving training programs can effectively and efficiently enhance drivers' skills, with a particular emphasis on higher-order driving skills, which offer significant benefits.

B. Gamification on Driving

Gamification refers to the use of game design elements in non-game contexts, which can enhance user engagement and retention [7]. The five main principles of gamification are (1) goal orientation; (2) achievement; (3) reinforcement; (4) competition; (5) fun orientation. Layered goal orientation allows learners to progress systematically from a beginner to an expert or master as they demonstrate mastery of skills and knowledge. By incorporating gamification techniques in applications and processes, it is possible to improve user engagement and learning by transforming an activity or

process into a computer game [8]. Previous studies have demonstrated the effectiveness of gamification on education, such as teaching computational thinking [9, 10] and improving English vocabulary [11, 12]. System design elements, such as points, levels, leaderboards, badges, challenges, feedback, rules, visual/3D space/sounds, etc., are designed and mapped to gameplay to enhance the user experience for gamification.

Applying gamification techniques to road safety can motivate drivers to engage in safe and courteous driving behaviors [13]. It can lead to greater engagement, fun, and motivation for users in the automotive domain. There have been several examples of the use of game elements and mobile devices to influence driver behavior, such as Nissan Leaf's use of game elements to encourage environmentally friendly driving by rewarding users who drive economically. Government-funded interventions have also used online games to educate learner drivers on on-road risks and safe driving behavior [14].

Harro Besier [15] created a 3D Driving Academy that monitors driving rules in six different countries. These driving simulators have been explored for their potential to train learner drivers, primarily for their ability to provide a safe environment in which to encounter hazards [14]. With fun, interesting, and addictive driving simulations, interactive applications allow users to influence outcomes, reward users for skills or knowledge gained, and learn from making virtual mistakes.

C. Review of Existing or Related Solutions

There are various solutions available for novice and learner drivers to enhance their driving skills or prepare for the driving test. These include attending driving school and receiving guidance from a driving instructor, playing driving simulator games, watching online videos, and reading the Road Users' Code booklet [16].

Attending driving school is a traditional and formal approach to learning and improving driving skills. Learners can acquire vehicle handling skills under the supervision of a driving instructor. However, it can be costly, inflexible, and formal pre-license driver training is not always effective in reducing novice drivers' crash rates [3].

Playing a driving simulator game offers high controllability and reproducibility. Players can practice driving in different virtual traffic, weather conditions, and road layouts, all of which can be manipulated by a computer. With gamification and simulation features, players can practice hazardous conditions without any physical risk [17]. However, some users may experience discomfort in a virtual environment.

To address the need for a highly functional and portable solution, a mobile application is an ideal option for providing access to training materials, driving tutorials, and games on smartphones. This cost-effective solution requires no additional equipment and includes gamification features that enhance engagement and cognitive absorption, leading to improved learning achievement. The application incorporates system design elements such as points, levels, leaderboards, and feedback to enhance the user experience. Table I summarizes the differences between existing solutions and our proposed solution.

TABLE I. COMPARISON BETWEEN DIFFERENT SOLUTIONS

	Portable learning	Cost-effective	Test routes revision	Hazard perception training	Gamification feature
Driving school	✗	✓	✓	✓	✗
Driving simulator game	✓	✗	✗	✓	✓
Test routes video	✓	✓	✓	✗	✗
Road user's code	✓	✓	✗	✗	✗
Our solution	✓	✓	✓	✓	✓

III. METHODOLOGY

We designed and developed a mobile-based application that simulates driving in the Ho Man Tin district. The application provides driving tutorials to reinforce driving knowledge, free driving to improve road recognition skills, and driving tests to prepare learner drivers for the actual driving test. The application includes three modes, namely Tutorial mode, Free Driving mode, and Driving Test mode, to cater to different users' needs.

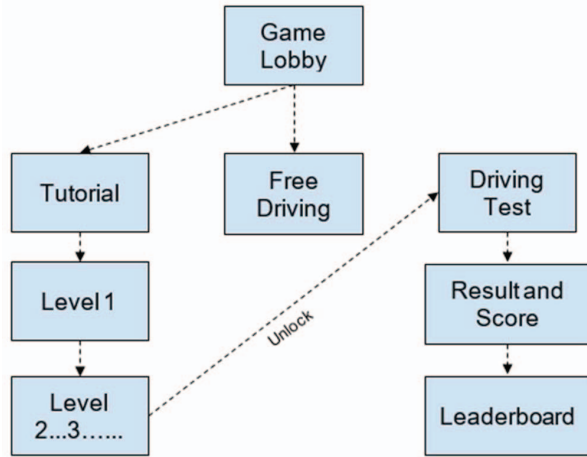


Fig. 1. Modes in the driving simulator app.

Through the application, app users can practice driving and improve their driving skills and learner drivers can practice for driving tests. We will evaluate the application's effectiveness to app users through pre and protests.

There is a server built to store the scores of a leaderboard. The leaderboard in Driving Test mode will display the 10 highest scores achieved by different app users. Updating and obtaining leaderboard scores requires an Internet connection. The server connection will not start if no Internet is connected.

A. Game Design

Tutorial Mode. The Tutorial Mode is designed to enhance drivers' skills and attitudes by providing training tutorials in various environments and situations. Each tutorial offers related teaching instructions and hints for the player to follow and achieve specific goals. A level unlock system is incorporated to increase players' motivation and sustain their engagement by balancing their knowledge and skills with the

challenge required to advance through the tutorials. Players must complete each level to unlock the next one, and this system is a gamification element that indicates progress towards higher-level goals and fulfilling intermediate goals.

After completing all tutorials, the Driving Test Mode is unlocked, motivating players to engage in the tutorials to reach this final stage. The tutorials are divided into three categories: Road Recognition, Reaction to Actual Driving, and Driving Habit Enhancement. Each category includes multiple tutorials with instructions or hints to teach players driving skills and prevent mistakes.

The Road Recognition category includes four tutorials that teach driving knowledge related to road markings and traffic components. The Reaction to Actual Driving category includes three tutorials that teach driving knowledge related to on-road handling skills and habits. The Driving Habit Enhancement category includes three tutorials that teach driving knowledge related to drivers' driving habits.

Free Driving Mode. The Free Driving Mode offers a realistic Hong Kong street view to enhance drivers' road recognition in the Ho Man Tin district. It allows players to freely ride and explore the district on the map we created without any teaching hints or restrictions for a better driving experience. The map is designed to reflect the actual situation, including roads, buildings, and street signs, to improve players' recognition of the district's roads. Rich 3D graphics and sounds are added to create an engaging virtual environment.

The Free Driving Mode lets players freely drive on the map we created, providing a highly simulated driving situation. Most traffic and street components, such as buildings, street signs, and decorations, are added to the map with rich 3D graphics. Non-player vehicles (NPV) and pedestrians are also included, following the traffic system and walking on the street. Players can drive freely in this mode with their driving habits without any penalties for making driving mistakes on the road. It is designed to allow players to explore and discover the high-quality map we created, enhancing their road recognition skills in the Ho Man Tin district.

Driving Test Mode. Once a player passes all tutorials in Tutorial Mode, Driving Test Mode is unlocked. It stimulates the private car driving test at Pui Ching Road Driving Test Centre, focusing on the road test part of the Transport Department's private car driving test. The road test consists of Part B, examining parking and U-turn, and Part C, examining on-road driving. The game simulates both parts of the test, with building appearances, road markings, and driving test procedures reflecting real situations. In this mode, players can choose to examine Part B or Part C of the driving test. Part B examines U-turn and parking skills, requiring the player to park the vehicle in a parking space and perform a U-turn in a specific place. Part C examines the candidate's on-road performance, with instructions guiding the direction and route that the player should take.

The game incorporates gamification elements such as points, leaderboards, and feedback to keep players interested and engaged [8]. A scoring system is designed to evaluate the player's driving performance, with points deducted for any mistakes made during the test. The player's score is 100 at the beginning of the test, with one point deducted for each mistake

made. The passing score is set at 90 points, and feedback is given on any mistakes made during the test.

A leaderboard is also included, displaying the top 10 highest scores achieved by different players with their names displayed. This feature encourages players to do well and keep engaging in the game to compete with other players.

B. User Interface

The user interface design of the mobile driving simulator is simple and intuitive. The game lobby includes four buttons for Tutorial Mode, Free Driving Mode, Driving Test Mode, and the leaderboard. In the game scene, buttons are located on the left panel to control the car's widgets, including the headlight and car indicator signal light. A control panel is located at the bottom of the screen, and driving mirrors are provided to help the player get used to the driving situation.

Players can control the vehicle in the game using their phone, and proper settings of car components are necessary for a realistic driving experience. Mirrors are placed in the user interface to show the driving environment backward. A rearview mirror is located at the top of the UI, and side mirrors are placed on the left and right-hand sides of the UI to provide a comprehensive view of the surroundings. The user interface is designed to be user-friendly, guiding players through the game and enhancing their driving experience.



Fig. 2. The user interface of the driving game scene.

C. Game Components

The mobile driving simulator is developed using Unity as the game engine and C# programming language to implement all functions and logic. The simulator includes a traffic system, road conditions, and a leaderboard system.

The traffic system includes traffic light control, non-player vehicles, and a traffic lane system. Traffic light control manages the whole traffic light system, controlling non-player vehicles and pedestrians' movements. Non-player vehicles are included to simulate real-world traffic conditions. The traffic lane system ensures that players follow traffic rules and regulations. If players do not follow traffic rules while driving, there will be warning feedback in the game, and their score will be deducted in Driving Test Mode.

Road conditions provide a realistic driving experience, including pedestrians, weather, and time changes in the gameplay. Pedestrians may walk on the pavement or cross the road on a zebra line or traffic light, and players need to be aware of unpredictable situations. Weather conditions such as foggy weather require players to turn on their headlights to ensure safe driving. The time changes also affect driving conditions; for instance, when the sun goes down, players need to turn on their headlights to maintain visibility.

A leaderboard system is developed for the Driving Test Mode, allowing players to connect to a database server via the Internet. This feature enables players to compare their performances, encouraging competition among players.



Fig. 3. Traffic lights (left) and pedestrians (right) in the game scene.



Fig. 4. Non-player vehicles in the game.

IV. EVALUATION

To evaluate the effectiveness of the application, we utilize pre-test and post-test methods. Interviewees are required to answer a quiz about road usage rules before and after using the application. By comparing the scores obtained by interviewees before and after using the application, we can measure the changes in their knowledge and skills.

A. Evaluation Plan

To evaluate the effectiveness and user experience of the application, we conducted a survey that included a pre-post-test and a Likert scale with 10 participants. The pre-test survey was conducted before using the application and included three parts: (1) gathering interviewees' information, (2) assessing their understanding of the driving test procedure, and (3) completing a quiz. The post-test survey was conducted after using the application and included three parts: (1) evaluating their understanding of the driving test procedure, (2) completing a quiz, and (3) reviewing their user experience.

B. Result Analysis

Table II. shows our interviewees have limited driving experience (80% give 1) and are unfamiliar with the driving test procedure (50% give 1 to 2). As our target users are novice and learner drivers, Table II. indicates that all of our interviewees fall under this category.

The test involved 10 candidates, with an average pre-test score of 2.3 out of 5 and an average post-test score of 3.4 out of 5. The correlation between pretest and post-test scores is 0.873, with a significant value of 0.001, indicating a

significant positive correlation between the two samples. The results demonstrate the effectiveness of the application in teaching driving knowledge to novice and learner drivers, with an improvement of 1.1. The t-value of the difference between samples is -0.69393 and was found to be significant (< 0.05).

TABLE II. STATISTIC OF INTERVIEWEES (PRE-TEST)

	1	2	3	4	5
I am an experienced driver.	80%	10%	10%	0%	0%
I want to join the driving test.	0%	0%	40%	20%	40%
I am familiar with the driving test procedure.	10%	40%	0%	40%	10%
I am familiar with the requirements of the driving test part B.	10%	50%	0%	40%	0%
I am familiar with the requirements of the driving test part C.	10%	50%	0%	40%	0%
I want to learn to drive with a portable application.	0%	0%	10%	50%	40%

Table III. reveals that our application effectively helps novice and learner drivers learn about driving skills and rules (50% give 5). The majority of our interviewees strongly agree that the application's map is authentic (70% give 5) and assists in recognizing the roads of Ho Man Tin. Additionally, the application aids users in recognizing roads. However, the table indicates that we need to improve our user interface to make it clearer and smoother (30% give 2).

TABLE III. STATISTIC OF INTERVIEWEES (POST-TEST)

	1	2	3	4	5
I think this application help me to learn to drive.	0%	0%	10%	40%	50%
I think this application runs smoothly.	0%	30%	30%	30%	10%
I think the UI of this application is clear.	0%	0%	50%	40%	10%
I think the map of this application is authentic.	0%	0%	0%	30%	70%
I think this application help me to learn more about the driving test.	0%	0%	10%	70%	20%
I think this application improve my confidence in driving tests.	0%	0%	40%	40%	20%

V. DISCUSSION AND FUTURE WORK

We have fully implemented a mobile game to improve the driving experience and performance of novice and learner drivers, leveraging the high penetration rate and portability of smartphones. Our game includes 10 driver-training tutorials to enhance novice drivers' skills and a simulated driving test to allow learners to practice for the actual test. Additionally, we have incorporated AI pedestrians and vehicles to create a more engaging driving environment for players. We believe players will enjoy exploring the virtual map we have created.

However, our driver-training solution has limitations. Some driving skills, such as blind spot observation and vehicle handling, cannot be learned through a smartphone. Blind spot observation is a crucial aspect of driving, and without observing the actual head movement of the player, we cannot replicate this action in our game scene. Additionally, vehicle

handling skills cannot be adequately practiced through our game's button controls, as they differ significantly from driving a real vehicle. This trade-off between portability and reality poses a challenge for our solution.

Furthermore, our solution is limited to Ho Man Tin, with the Pui Ching Road Driving Test Centre as the basis of our simulated driving test. However, there are 17 driving test centers in Hong Kong, each with its driving test routes, and learners attending other driving test centers may not benefit from our solution.

To overcome these limitations, we can implement our driver-training solution into virtual reality (VR) and augmented reality (AR) environments, providing a more realistic game scene to players. Prior research has demonstrated that VR and AR are effective in educational contexts [18-21]. With the use of VR headsets, we can detect players' head and eye movements, which allows us to enhance our solution with blind spot observation. By configuring additional gaming equipment, i.e., steering wheels and pedals, we can also provide training for vehicle control skills. Implementing AR into our mobile driving game can provide a more engaging and immersive gaming experience for the player while also increasing their situational awareness and decision-making abilities.

Additionally, we can expand our map beyond Ho Man Tin, creating a larger map that includes other parts of Hong Kong, such as Hung Hom, Kowloon Tong, Mong Kok, and more. We can also implement more driving test routes from different test centers, allowing more learner drivers to benefit from our game for driver training and preparation for the driving test. In the future, the driving simulator can be extended to offer driver status detection, such as drowsiness and stress detection [22, 23].

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