Game Suite for Transportation Education

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Dr. Montasir Abbas is an Associate Professor in the Transportation Infrastructure and Systems Engineering at Virginia Tech. He holds a Bachelor of Science in Civil Engineering from University of Khartoum, Sudan (1993), a Master of Science in Civil Engineering from University of Nebraska-Lincoln (1997), and a Doctor of Philosophy in Civil Engineering from Purdue University (2001).

Dr. Abbas has wide experience as a practicing transportation engineer and a researcher. He was an Assistant Research Engineer and the Corridor Management Team Leader at Texas Transportation Institute (TTI), where he has worked for four years before joining Virginia Tech. Dr. Abbas conducted sponsored research of more than $720,000 as a principal investigator and more than $750,000 as a key researcher at TTI. After joining Virginia Tech, he has conducted over $2,400,000 worth of funded research, with a credit share of more than $1,750,000.

Dr. Abbas is an award recipient of $600,000 of the Federal Highway Administration Exploratory and Advanced Research (FHWA EAR). The objective of the FHWA EAR is to “research and develop projects that could lead to transformational changes and truly revolutionary advances in highway engineering and intermodal surface transportation in the United States.” The award funded multidisciplinary research that utilizes traffic simulation and advanced artificial intelligence techniques. He has also conducted research for the National Cooperative Highway Research Program on developing "Traffic Control Strategies for Oversaturated conditions” and for the Virginia Transportation Research Council on "evaluation and recommendations for next generation control in Northern Virginia."

Dr. Abbas developed Purdue Real-Time Offset Transitioning Algorithm for Coordinating Traffic Signals (PRO-TRACTS) during his Ph.D. studies at Purdue University, bridging the gap between adaptive control systems and closed-loop systems. He has since developed and implemented several algorithms and systems in his areas of interest, including the Platoon Identification and Accommodation system (PIA), the Pattern Identification Logic for Offset Tuning (PILOT 05), the Supervisory Control Intelligent Adaptive Module (SCIAM), the Cabinet-in-the-loop (CabITL) simulation platform, the Intelligent Multi Objective Control Algorithms (I-MOCA), the Traffic Responsive Iterative Urban-Control Model for Pattern-matching and Hypercube Optimal Parameters Setup (TRIUMPH OPS), the Multi Attribute Decision-making Optimizer for Next-generation Network-upgrade and Assessment (MADONNA), and the Safety and Mobility Agent-based Reinforcement-learning Traffic Simulation Add-on Module (SMART SAM). He was also one of the key developers of the dilemma zone protection Detection Control System (D-CS) that was selected as one of the seven top research innovations and findings in the state of Texas for the year 2002.

Dr. Abbas served as the chair of the Institute of Transportation Engineers (ITE) traffic engineering council committee on “survey of the state of the practice on traffic responsive plan selection control.” He is also a member of the Transportation Research Board (TRB) Traffic Signal Systems committee, Artificial Intelligence and Advanced Computing Applications committee, and the joint subcommittee on Intersection. In addition, he is currently a chair on a task group on Agent-based modeling and simulation as part of the TRB SimSub committee. He also serves as a CEE faculty senator at Virginia Tech.

Dr. Abbas is a recipient of the Oak Ridge National Lab Associated Universities (ORAU) Ralf E. Powe Junior Faculty Enhancement Award and the G. V. Loganathan Faculty Achievement Award for Excellence in Civil Engineering Education. He is also a recipient of the TTI/Trinity New Researcher Award for his significant contributions to the field of Intelligent Transportation Systems and Traffic Operations.
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Abstract
Educational games have been proven to be effective tools to support transportation engineering education. Our group has been actively developing educational games for teaching transportation engineering classes. This work identified the key concepts in transportation engineering that can be gamified. Five games were developed targeting five areas in transportation. The developed games are Transporters for planning, Time-space Invaders for signal control, DZ-Man for safety, Angry Curves for highway design, and Road Crush pavement design. All the games can be played online after users’ registration and logging-in. The users’ gameplay data were uploaded to a server. A record of gameplay data include the user name, the game played, the level number in the game, the game parameters (e.g., the game scores), and the time that record was generated. We evaluated the effectiveness of the games by before and after studies. The students were asked to do quizzes after learning a certain concepts during the class. The quizzes were targeting the concepts taught in the class. Then they were asked to play a game targeting the same concepts and do the same quizzes again. We compared the quizzes scores before and after the gameplay to tell the effectiveness of the games. The games were evaluated in 2014 and 2015 during a transportation introductory class. The results showed that for all the tested games, the overall students’ quizzes scores increased. t-tests were conducted for each evaluation and the results showed the increases were statistically significant. The results indicate that the games can improve students’ learning outcomes significantly. This paper can be used to guide developers to build new games for transportation engineering education. This paper can also be useful for transportation educators who want to implement games in their teaching practice.

Keywords:
Game-Aided Pedagogy, Gravity Model, Learning Outcomes

1. Introduction
More and more educators agree that games can be used as effective tools for their education practice. Until now, most game-involved education practices are for K-12 group \cite{1, 2}. At the same time, it’s rare to find games being used for higher education. This phenomenon exists because the target knowledge for K-12 group can be more easily delivered through existing games, when compared to the target knowledge in higher education.

The nature of transportation education requires students to observe, design, and interact with the transportation system. Unlike chemical engineering, transportation experiments require large scale field experimentation and have human factor impacts, so lab-work-based learning approaches do not always work. Simulation software can be used to form a virtual lab that allows students to explore. However, learning the simulation software is as hard, if not harder, as learning the concepts in transportation engineering itself. An intuitive interface between the
simulation software and the students is needed. Customized developed games can be a good interface to show the students enough but not too much information with pleasant learning experience.

Our Lab has been actively developing transportation education games. There are five games that have been developed in this game suite. These games target concepts in pavement design, highway design, traffic safety, traffic control, and traffic planning. Wang et al. developed the first game (DZ-Man) in this suite in 2014 [3]. A gravity model was proposed at the same time to describe the knowledge delivering dynamics and can be used to model the engagement of the students in such educational games [4]. The gravity model was further used to compare two different educational games developed by the group [5]. The five games were presented in Transportation Research Board annual meeting in 2017 [6]. The games were distributed among the transportation education community through the meeting.

At this stage of the project, the games can be accessed online. The games were updated based on the feedback from the users. This paper presents the updated educational game suite as well as the newly raised security issues and the solutions. This paper could serve as a guide to the educators who want to implement the developed games in their classes. It could also serve as a reference for education researchers who want to conduct projects regarding game-aided engineering education.

2. The Games for Transportation Education

To build a transportation system in real word, there are certain processes that need to go through. We need to plan first to know where to allocate the buildings and how to connect them with roads. Then geometry design of the highways come to the stage. Before the actual road construction, pavement design should be conducted. When traffic is loaded to the road, proper traffic control strategies should satisfy the safety and efficiency requirements.

These processes cover certain topics in transportation education. These topics include traffic planning, highway design, pavement design, traffic safety, and traffic control. Corresponding to these topics, we designed five different web games, i.e., Transporters, Angry Curves, Road Crush, DZ-Man, and Time-Space Invaders. These games are hosted in a website server. Students can play these games online after register and login. The server stores the users’ information and their gameplay data. A record of gameplay data include the user name, the game played, the level number in the game, the game parameters (e.g., the game scores), and the time that record was generated. In the rest of this section, we will present each of these five games.

2.1 Transporters

Transporters game is a game for traffic plan. The game UI has draggable tiles and a playground to which the players can drag tiles (as shown in Figure 1). The tiles represent road segments and
trip zones. They players need to place the tiles in appropriate locations such that the traffic network will not be congested.

The Transporters game uses four step model (a conventional traffic forecasting model [7]) to evaluate the players design. The game gives the players visual feedback by highlighting the congested road segments with red color and the uncongested road with green color.

![Game User Interface for Transporters](image)

**Figure 1. Game User Interface for Transporters**

### 2.2 Angry Curves

Angry Curves game targets concepts in highway design. Players need to design the curvatures and super-elevations of the curves with given constrains. If the highway was designed properly, the game will show an animation of vehicles running on the designed highway nicely. If the design does not meet the safety requirement, the game will show an animation of vehicles been thrown away by the highway. A screenshot of the Angry Curves game is shown in Figure 2.
2.3 Road Crush

Road Crush is a game targeting concepts about pavement design. In pavement design, the typical design parameters are the material and the thickness of each layer. In this game, players need to design a segment of pavement by dragging the material tiles into proper layers and adjusting the thickness of each layer. Vehicles will stop moving and a crack will be shown in the pavement if the design does not meet the requirements, which means the road was crushed. If the design can handle the traffic on it, the game will show a check mark. A screenshot of the case where the design does not meet the requirement is shown in Figure 3.
2.4 DZ-Man

Dilemma Zone (DZ) is a zone where drivers cannot decide whether to stop or to go when approaching an intersection at the onset of yellow. In practice, various types of Green Extension Systems (GES) were used to protect DZ \(^8\). In this game, players need to mimic the GES to control the traffic light and decide when to stop the green. When a player stop the green, the vehicles in DZ will be in red and other vehicles will be in green. A screenshot of DZ-Man is shown in Figure 4.
2.5 Time-Space Invaders

Time-Space Invaders is a game targeting coordinated signal control concepts. It uses a GM model (a car following model [9]) to simulate the vehicles’ movement. Players can adjust the offset of an intersection by dragging the arrow (as shown in Figure 5). The game shows time-space diagram as feedback. Delay is also shown in the game as costs.

3. Preliminary Tests and Results

We conducted a Before-and-After study to test the effectiveness of the games for improving students’ understanding of the targeting concepts. The study process can be summarized as “lecture-quiz-game-quiz” processes. The students were given lectures on specific topics in the class of Introduction to Transportation. Introduction to Transportation is a class that covers all
the five topics in transportation education. Then they were asked to finish a set of untimed quizzes related to a topic learned in the class. They were then asked to play a corresponding game. They can play the game as many time as they want. They were asked to do the same quizzes again after they finished the game play. No feedback was given to the students regarding their performance in the pre-game quizzes. Therefore, the only factor that can affect their scores is the gameplay between the two sets of quizzes. The quizzes were designed as multiple choices, which avoid the effect of graders’ subjective bias.

We conducted studies for DZ-Man in 2014 and 2015 and a study for Angry Curves in 2015. The experiments were approved by the Institution Review Board (IRB). There were 10 questions associated with the DZ-Man, and 7 questions associated with the Angry Curves. An example of the question is shown in Figure 6.

![Post-Game Quiz](image)

**Figure 6. Screenshot of One Question**

We conducted matched pairs T-Tests to compare the students’ quizzes scores. The results are shown in Figure 7. From the results, it can be seen that the mean difference are all around 1. This means the students’ average quiz score increased by 1 (out of 7 for Angry Curves game and 10 for DZ-Man game) in all the cases. The significance levels are 0.0051 for 2014 DZ-Man data, 0.0006 for 2015 DZ-Man data, and 0.0006 for 2015 Angry Curves data. This means the increases of students’ understanding on the targeted concepts (reflected by the quiz scores) are statistically significant.
4. Beyond the Campus

At this stage of the project, we allow users from all over the world to have access to the games. This means the users of the games will no longer be limited within campus. The players’ data will still be collected for further research purpose. The paper-based consent material cannot reach the users over the internet. The old online quiz system needs the team to add users manually to the system to allow their access. It is no longer practical to use the old online quiz system with potentially massive users. Double login (login to the game and login to the quiz system) should no longer be needed when the games and the quiz are hosted in one website. The way from which the students get to know the games is no longer limited to the assignments. The players may not be able to read the introduction of the games which was included in the description of the assignments. Those newly raised issues need to be solved.

4.1 Web-based IRB Protocol Updates

The user group need to be expanded to potentially anyone who meets the minimum requirement on the internet. In order to do so, we need to update the IRB protocol. To update the IRB protocol, we did the following tasks:

- Upgrade the website security. Several security risks have been fixed.
- Change the paper-based consent form into web consent form. The users need to agree to the web consent form to finish the registration. The registration webpage is shown in Figure 8.
4.2 Online Quiz System

In the studies where students were within Virginia Tech, students can take the quiz in Scholar quiz system (as shown in Figure 6). Scholar is an online learning management system. Only students added into a class in Scholar have access to the quizzes. This was convenient when the games were tested within campus. Now since the games is open to anyone on the internet, a new online quiz system is needed.

We updated the database structure to store the user-quiz information. Two data tables were used. One table stores the data indicating if the user finished the quizzes; another table stores users answers and scores. When a user goes to a game page, the server will check if this user have done the quiz for this game. If this user did the quiz before, the server will allow the user to play the game. If not, the server will redirect the webpage to the quiz page. After the user submit the quiz answers, the server will redirect the webpage to the game page. The quiz pages are in HTML form format. An example of the quiz webpage is shown in Figure 9.
We updated the games and website so that the players only need to login once to the website to play all the games and do the quizzes. A flow chart of login process is shown in Figure 10. After a user logging in successfully, the server will put the user ID information into a Session. A Session is where the data of one browser/server conversation can be stored temporarily in a server. The server will then redirect the webpage to the homepage where the player can choose which game to play. After the player choose which game to play by clicking on a link, the server will query its database to see if the player has done the quiz at least once for this game. If has done the quiz, the player will be able to play the game directly. If not, the webpage will be redirected to the quiz webpage. Only after the player finishes the quiz, the game page can be shown. The quiz answer will be uploaded to the server with the user ID stored in Session. For Transporters, Angry Curves, Road Crush, and DZ-Man, they were developed in Unity. They cannot access the information in Session. However they can access the parameters in the URL that host them, so we put the user ID as a parameter in URL. To prevent faking identity, the webpage will check if the user ID in the URL parameters matches the user ID in Session. If they match, the page will stay and the game will be loaded. If they do not match, the page will redirect itself to a URL with the correct user ID in its parameters.
Figure 10. Unified Game Login Mechanism

4.3 Integrated Game Introduction

We updated the games such that they all have introduction scenes at the beginning of the games. The introduction tells the players what they should do in this game. The players can skip the introduction if they do not need to see them, e.g., they have already seen the introduction. A screenshot of the introduction scene of DZ-Man is shown in Figure 11.
5. Conclusion and Future Work

In this project, five web games have been developed targeting five topics in transportation education. They are now available to the public. Before-and-after studies showed that the educational games can improve students’ understanding of the targeted concepts significantly. Updates were made to encounter the issues faced when the games opened to larger scale of audiences.

For the future work, the team will keep collecting feedback for the games and make updates and revisions to meet the requirements from the broader user group.

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