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Game-Aided Pedagogy to Improve Students' Learning Outcomes and Engagement in Transportation Engineering

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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.

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Game-Aided Pedagogy to Improve Students' Learning Outcomes and Engagement in Transportation Engineering

I. Introduction and Overview

Learning in the Transportation Engineering field requires thorough content knowledge and a sound conceptual understanding of applied engineering principles. Delivery of course content needs to utilize a platform for creative instructional activities that can capture and maintain students' attention towards the course objectives. Computer-based educational games can be modeled to deliver specific learning objectives and supplement adaptive learning, role-play, and simulations [1]. Previous research concluded that the introduction of a game into a course can motivate students toward understanding the course material [2]. Well-crafted games can transfer knowledge in an efficient way and help students understand the concepts better, as shown in tests with increased scores compared to students who follow traditional text book learning [3]. Games appear to be effective teaching tools for concepts that require repetition for proficiency [4], and should be used as supplements that encourage students to understand and enjoy learning [5].

The goal of this research effort is to go beyond the development or use of games in the classroom. **Our objective** is to investigate and design a game-aided pedagogy to improve students' learning outcomes and engagement in transportation engineering. We propose a cyclic approach to design and implement games into the curriculum of several transportation courses, and assess their values. The results of our analysis will be used to enhance the games and increase their effectiveness. The focus of this project is not only the development of the tools, but also to increase our understanding as educators about the students' learning outcomes and effective game teaching methods. At the end of this project, we will produce web games with an effective set of exercises that can be used by faculty members at other universities.

A. Educational Games and Learning

Educational games and simulations have been argued to help students both achieve learning gains, and improve engagement in knowledge fields. Games are a form of active learning, in which students are not passive recipients of information but rather active, in control, and challenged to reach a certain goal [6]. Also, games can encourage iterative practice of concepts that is often necessary in learning [7]. Pure intrinsic motivation—learning for the love of learning—is rare, and learners are more likely to repeat learning activities if the teaching tools are truly learner-centered and fun [8]. Games can offer learning experiences that are more enjoyable than the traditional methods and target new ways of learning. In fact, there is widespread agreement that "learners have changed in some fundamentally important ways" and that learners are now "deeply experienced" in a new form of (computer-enabled) play [8, pp 5-6]. Games can structure "learning through experience," and they can "engage new groups of learners" [9]. Thus games offer an alternative mode of learning that can be used to supplement traditional methods such as lectures, reading assignments, and pencil-and-paper homework. Delwiche 2006 provides a list of factors to pay attention to in developing and using game-aided pedagogy: (a) the interface must be easy to navigate; (b) interaction between players should result in greater engagement; (c) group gaming sessions should also increase engagement; and (d) the game must link to learning gains [10].

Furthermore, games based on interactive technologies can "create new opportunities for curriculum and instruction by bringing real-world problems into the classroom for students to explore and solve" [11, p 195, 12]. This approach is more active and learner-centered than traditional learning from lectures and texts, and therefore offers a potentially important link between different modes of learning and teaching. In fact, this challenge of "better alignment of faculty skill sets with those needed to deliver the desired curriculum in light of the different learning styles of students" has been a focus of the National Academies and Civil Engineering for several years [12, 13], and the use of digital technologies has been cited as holding great potential for pedagogical innovation.

B. Enhancing the Transportation Curriculum

Transportation engineering is a rich, yet challenging area to study as it has many active and inter-connected complex subsystems (e.g., drivers, vehicles, roads, decision making, algorithms). Transportation students can gain deep understanding of these subsystems with well-designed games and educational modules. Our experience indicates that students' learning is improved when the material taught is stimulating to students' curiosity and competitiveness. Past research has recognized the need to deliver transportation engineering education in appropriate ways for a new generation of students, including the development and implementation of summer workshops [14] and games [15]. This research showed the potential of outreach through the increase of interest among high school students in transportation careers and the increase of awareness of traffic engineering issues. However, these efforts focused on isolated development, and not on the effectiveness assessment of these educational innovations and their relation to meaningful student understanding [16]. There is therefore a need for integrating educational game modules with teaching and assessment [15].

We have used JEOPARDY!™-like games for review sessions and the outcomes of these activities were appealing. Students have indicated, during focus groups and personal communication, that they felt better prepared and more comfortable with the course material after these kind of activities. However, games such as JEOPARDY!™ lack the capability of in-depth illustration of challenging concepts. In addition, they don't provide students with the capabilities to spend more time, in a private environment, to understand certain concepts better. In this project, we propose to develop games that can intelligently illustrate complicated concepts and that are also appealing to students.

We have developed a prototype game and tested it for a particular subject in traffic engineering. In addition, Table 1 list a preliminary list of other game concepts we are currently evaluating to apply decision making/game play in different transportation areas to engage students. These game modules will be tested in appropriate courses, as listed, and will be improved based on feedback received from the students and from our faculty advisory board. We will post all games on our website and provide access to faculty at other universities to freely use them and provide an example that can be followed in other STEM fields. Each game will be packaged with associated instructional tools that include assignments and assessment tools.

Table 1. Proposed game modules in Undergraduate Transportation Curriculum

Course	**Game Module**	**Game Play**	**Objective**	**Example Learning Outcome**
Introduction to Transportation	Intersection design	Allocate proportions of available green times to different movements for different traffic volumes	Minimize traffic delay	Design efficient timing plans
Traffic Engineering	Driver behavior	Choose best time to end the green for different traffic scenarios	Minimize number of vehicles caught in dilemma zone	Model and calibrate car-following models
Traffic Safety	Run-off-the-road accidents	Choose best horizontal and vertical road curve parameters for different budgets and costs	Maximize driving comfort and minimize the frequency of crashes	Design safe road geometry
Transportation Planning	Traffic forecasting	Produce best road connection configuration for a given network set of nodes and budget	Minimize resulting traffic congestion	Model route choice and predict traffic volumes
Pavement Design	Equivalent Single Axle Load (ESAL)	Allocate predetermined amounts of road material to different roads for different ESAL values	Sustain given ESAL values on predetermined routes	Estimate ESAL values and design strong pavement

II. Illustrative Prior Work

Since the selection of the five modules will be finalized during the spring semester of 2014, we will present our preliminary work in one of the modules in enough details to illustrate the approach that we will follow in designing the rest of the modules. Our preliminary work focused on an important traffic engineering subject: dilemma zone protection issues. When traffic signals change from green to yellow, drivers have to make a decision whether they can safely stop (at an acceptable deceleration rate) at the intersection or continue and clear the intersection. Parameters such as distance from the intersection, speed at which they are travelling, and headway from the other vehicles, affect the drivers' decision in the dilemma zone. Drivers who encounter the yellow indication when they are far from the signal tend to stop, while those who are close to the signal tend to proceed. Between the two extremes, a "dilemma zone" exists where drivers are not clear on the best decision to make.

The probability of accidents in the dilemma zone is high. Generally, two types of accidents occur: 1) rear-end collision, when the driver in the front decides to stop and the driver behind decides to go, and 2) right-angle collision, when the driver decides to cross the intersection and unknowingly runs the red light and collides with the conflicting traffic. There are several methods and algorithms in the traffic engineering field that are designed to end the green indication at specific times to eliminate or reduce the dilemma zone. One of these algorithms is a detection-control system (D-CS) that monitors the location of vehicles in real-time and terminates the green only when no vehicle exists in the dilemma zone. This algorithm, however, is constrained by existing traffic controller's limits and traffic characteristics and needs to be described in this context.

The dilemma zone concept is traditionally taught to students through conventional teaching methods. Textbooks and lecture notes provide a general idea of the dilemma zone as a definition and a static pictorial representation. These methods could be confusing to students and lacking comprehensive illustration of the concept. Games on the other hand can provide a visual representation of the dilemma zone and illustrates the dynamics of the system, which is helpful for the students to completely understand the situational meaning of the concept. The concepts associated with the traffic signal controller algorithm (to decide when to end the green indication in response to existing traffic characteristics) are better illustrated with repetitive, yet insightful, examples of different traffic streams, where the student can get an instantaneous illustration of the impact of his/her control decision.

A. Web Game Prototype

The objective of the game prototype was to help students understand what might be the drivers' decisions at the onset of yellow based on the existing traffic conditions. The student who is playing the game has to determine the safe time to end the green indication so that the least number of cars in the dilemma zone exists and the crash hazard for the traffic is minimized. The game was developed so that it retrieves the decision of the virtual driver from a pre-loaded database that was calibrated to a real intersection data. The game also provides feedback in the form of a Hazard Value (measuring the potential for an accident), Least Hazard value (providing a feedback at the end of the game for the best possible score), and Time to Least Hazard Value (providing the best solution to the existing traffic stream). As an instant visual feedback, the vehicles that are caught in the dilemma zone are shown in red and the rest of the traffic is shown in green. The game also illustrates the traffic movement and how individual drivers try to adjust their speeds depending upon the headway from the car ahead of them. The game helps the player visually recognize the basic traffic parameters that affect the signal settings like the acceleration of the traffic, deceleration of the traffic, time to stop bar, etc. The game has two databases in the background which help to collect the information and send decisions to the traffic. The GUI of the game is shown in Figure 1.

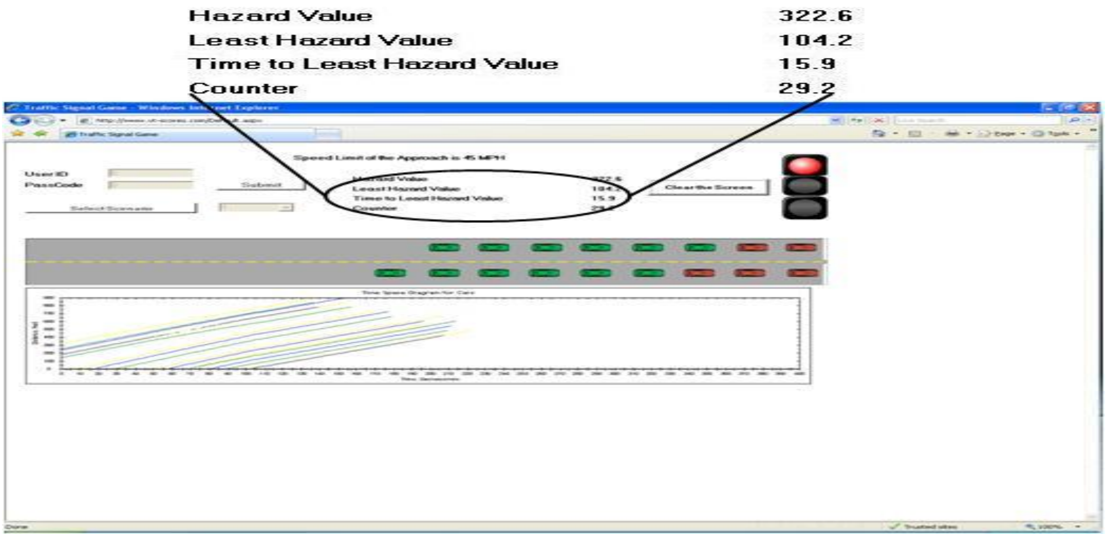


Figure 1. Interface of the Game Prototype

The game is presented to the player through a web page. The player is given a choice of traffic scenarios. The player has to terminate the green within 40 seconds from the start of the game (emulating an actual controller's operation). Upon terminating the green, the game logic moves to the databases. One database is programmed to collect the information of the player's decision and the other database is used to feed the information back to the traffic model to act accordingly as illustrated in Figure 2.

The game architecture consists of three layers: User Interface, Game Control, and Data Sources as described below. The 3-tier architecture (Figure 3) is chosen to assure the security of the database on the web.

- User Interface Layer: A web-based user interface displays simulated traffic flows. This layer receives a game player's commands and provides operation feedbacks, as well as time-based plots. Both DHTML and JavaScript are utilized to design a dynamic user interface.
- Game Control Layer: This layer implements logic controls based on game context and user's commands. It generates simulation traffic, loads initial traffic data, and stores instant traffic flows. The layer is programmed using Visual C# and SQL.
- Data Source Layer: This layer contains two databases. The traffic snapshot database stores the required information to initialize the game and the traffic scenario database is used to maintain the traffic flow when the yellow signal is given. Microsoft Access and SQL Server are utilized as the physical database. The programming language is SQL.

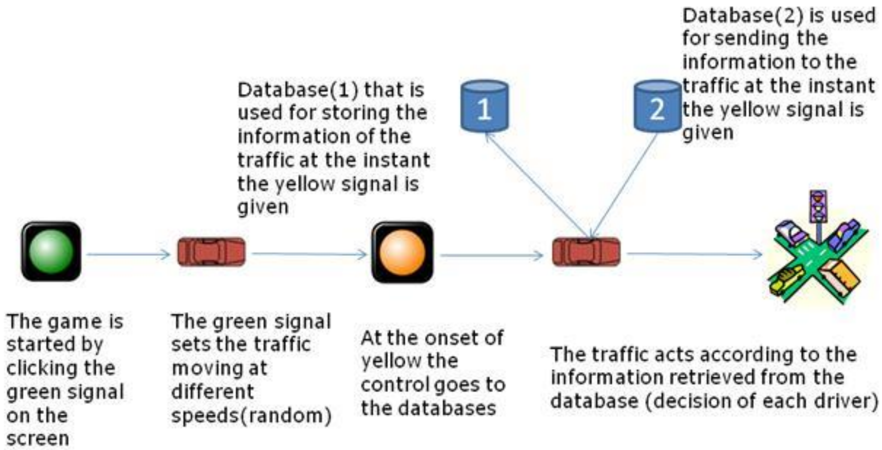


Figure 2. Overview of the Program Control

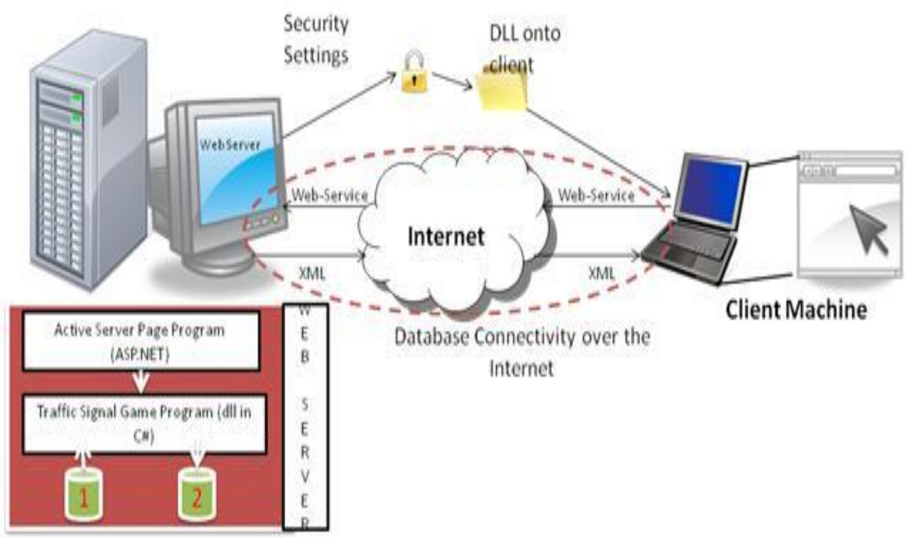


Figure 3. Architecture of the Game Prototype

B. Assessment and Evaluation

The game was integrated into a senior-level Traffic Engineering undergraduate course. To assess the effectiveness of the traffic controller game on student engagement, we used a three-phase survey process, combined with an end-of-term focus group. Students were divided into two groups that each completed two different homework assignments, one mainly focusing on the lecture delivered in the class and the other specifically designed to assess the understanding of student learning through the game. After attending the lecture, each group was asked to complete a different assignment: Group-1 was asked to complete the game-related homework (after playing the game) and Group-2 was asked to complete a traditional homework (not having played the game yet). Afterward, each group was given the other homework respectively. After each activity the students were asked to fill out a survey form designed to assess student engagement.

The surveys are modeled on the 16-question Situational Motivational Scale (SIMS) developed by Guay, Vallarand, and Blanchard [17]. To assess student engagement with respect to using the game for learning about traffic engineering, we used the data collection timetable shown in Table 2 below.

Table 2. Timetable for Data Collection

Date	Instrument	Time required
Before the lecture is delivered	Survey 1: Engagement in using learning technologies	5-7 minutes
Immediately following the submission of Homework I (Group 1 game homework and Group 2 lecture homework)	Survey 2: Engagement in course content on driver behavior at signalized intersections in the Traffic Engineering Course	5-7 minutes
Immediately following the submission of Homework II (Group 1 lecture homework and Group 2 game homework)	Survey 3: Engagement in course content on driver behavior at signalized intersections in the Traffic Engineering Course	5-7 minutes
Last week of class/exam week	Focus group interview	45 minutes

Our assessment and evaluation design was based on two pedagogical issues: (1) measurement and analysis of student engagement and (2) measurement and analysis of the students' learning outcomes.

Measuring Student Engagement

The Situational Motivation Scale (SIMS) [17] is designed to assess four constructs of motivation that, according to self-determination theory, underlie the initiation and regulation of human behavior. Specifically, self-determination theory conceptualizes human behavior in terms of true free choice, "a sense of feeling free in doing what one has chosen to do" [17]. The four types of motivation differ in their inherent levels of self-determination according to their position on a continuum that includes intrinsic motivation, identified regulation, external motivation, and amotivation. Self-determination theory further postulates that "the needs for competence, autonomy, and relatedness are central concepts" to understanding motivation [17]. Validation tests of the SIMS have indicated that intrinsic motivation and identified regulation lead to the most positive outcomes, such as persistence; that external motivation can lead to the decrease of intrinsic motivation; and that amotivation leads to the most negative outcomes, such as depression and feelings of incompetence. The SIMS is a self-report measure of situational motivation, i.e., "toward a single current situation" [17]. Thus, in experimental settings it has been used during and after a specific task.

In terms of engagement or motivation in a general sense, the authors state that further work is needed to understand how specific effects on motivation influence behavior over time. However, Vallerand [18], in his Hierarchical model, proposes that “cumulative motivational changes at the situational level produce over time an effect on more general motivational aspects” [18]. For example, repeated instances of loss of intrinsic motivation may over time affect motivation toward a certain situation and even have a global impact on a person’s everyday life [18].

We assessed engagement in the game activity, using the constructs of motivation as a measure of how each individual interacts with this specific task. However, without a longitudinal study, we can only extrapolate from these situational results using prior research and theory. The self-determination theory operationalized by the SIMS has been researched and tested since 1971 [19], with steady progress toward understanding how people initiate and regulate their own behavior.

The assessment of engagement with the game was conducted by students filling out a questionnaire with 16 questions framed on the guidelines from the SIMS. In this questionnaire, we used a 7-point Likert-type scale by posing a statement and asking the students whether the statement ‘corresponds not all (1)’, ‘corresponds a very little (2), ‘corresponds a little (3) ’, ‘corresponds moderately (4)’ ‘corresponds enough (5)’ ‘corresponds a lot (6)’ or ‘corresponds exactly (7)’ for the SIMS questions and a scale from ‘strongly disagree (1)’, ‘disagree (2)’, ‘neutral(3)’, ‘agree (4)’, ‘strongly agree (5)’.

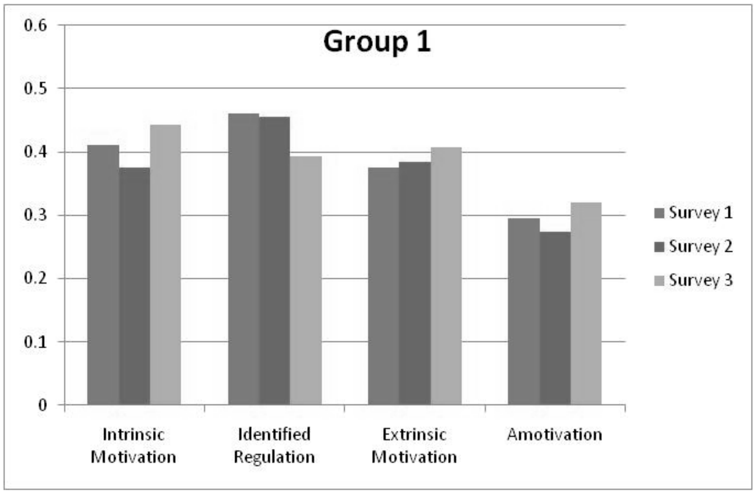
The results of the survey are presented in Figure 4. The figure shows two different graphs, one for each group, elaborating the four different motivating constructs in self determination theory. Figure 4-a shows the four SIMS factors for Group 1. Intrinsic motivation in self-determination theory describes situations in which a person is interested in performing an activity for itself, in order to experience pleasure and satisfaction inherent in the activity. It can be seen that the Intrinsic Motivation has a marginal decrease after playing the game (response to Survey 2) and as shown, there is an increase in the intrinsic motivation of the students after completing the traditional homework (response to Survey 3). It should be noted that the students were interested in playing the game and answered the related game questions adequately. Looking at the figure, our hypothesis is that the students felt that they have learned most of the concepts they needed to learn about driver behavior at the signalized intersection (by seeing it on the screen in response to every control action they took) and had, therefore, no further intrinsic motivation to learn more about the subject. This desire, however, increased again when they did the traditional homework assignment that presented them with different questions, making them realize that there is more to learn about the subject than they had previously thought. Figure 4-b (for Group 2) shows an increase in intrinsic motivation for the response of survey 2 (after completing the traditional homework) and decrease for survey 3 (after the game homework). This strengthens our hypothesis as the students might have felt more need to learn after doing the traditional homework, followed by more confidence in their knowledge after playing the game and solving its questions.

Identified Regulation describes behavior that is valued and perceived as being chosen by oneself, yet is still extrinsic because the activity is not performed for itself but as a means to an end. Figure 4-a and –b both show an identified regulation similar to that of the intrinsic motivation, except that the traditional homework did not increase the identified regulation measure for group one. This can be explained by students' realization that they do not need more understanding of the homework-specific material in the grand scheme of learning about driver behavior at signalized intersections in general.

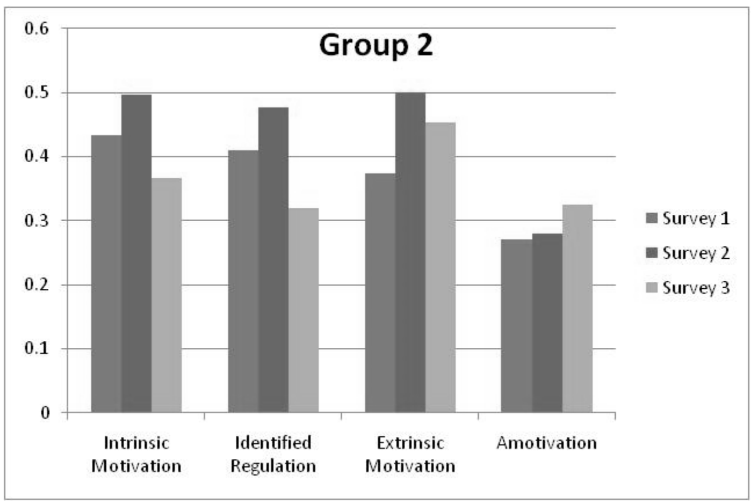
Extrinsic Motivation is the behavior regulated by rewards or in order to avoid negative consequences. Figure 4-a shows that there is an increase in the Group-1 students' motivation given additional rewards for solving both game-related and traditional homework. There is a slight increase in the extrinsic motivation for students in Group-1 in response to survey 3, which implies that students were more extrinsically motivated after solving the traditional homework. This is probably due to the fact that they did not do as well as they were hoping for, and hence there was a need for more rewards (e.g., better grade, more correct answers). Figure 4-b shows higher levels of extrinsic motivation after the traditional homework and lower levels after playing the game. Since this group played the game last, we hypothesize that they were not in need of more extrinsic rewards because solving the game homework provided them with an "extra credit" and they therefore had less need for extrinsic motivation than when they finished the traditional homework. However, both Group-1 and Group-2 showed more desire for extrinsic rewards after solving both homeworks than they originally started with. This could be explained either by the desire of students to obtain better grades as the semester progresses or a reflection of a general performance that is less than their desire or expectation in both assignments. Both graphs in Figure 4 show an increase in the percentage of students who might need external motivating factors, such as grades or extra credit, for learning the concepts. This suggests that a game coupled with additional rewards can be a useful tool for increasing the interest of the students in a course.

The amotivation scale describes situations in which individuals experience a lack of contingency between their behaviors and outcomes. This factor characterizes behaviors that are neither intrinsically nor extrinsically motivated. This behavior is the least self-determined because there is no sense of purpose and no expectations of reward or possibility of changing the course of events. The graph for Group-1 in Figure 4-a shows a decrease in amotivation after the game activity but an increase after the traditional homework activity. This suggests that the game was able to attract the students in group 1 to learn the concept. The graph for Group-2 in Figure 4-b shows an increase in amotivation both after completing the traditional homework activity and the game activity suggesting that the students in the Group-2 are neither intrinsically nor extrinsically motivated. Based on the amotivation results in Figure 4, it appears that a visualization of a concept can attract more attention from a student than traditional lecture-based homework and hence introducing a game-based activity before traditional assignment can work as an effective supplemental tool.

It could be seen from the above discussion that analysis of students' response could shed more light into the effectiveness of using games in the classroom. We will apply more detailed analysis of this nature in the project by students' groups, exercise assignment, and game module. This analysis will therefore allow us to measure and assess the students' engagement in the game. It should also be noted that using multiple game modules and larger student base will allow more in-depth analysis that could in turn improve the students' learning outcomes.



a) Group 1 results



b) Group 2 results

Figure 4. Graphs showing the survey results of Continuum of Motivation Constructs in Self-Determination Theory

Measurement and analysis of the students' learning outcomes

In this part of the development, we are testing the hypothesis that students who played the game before solving a homework assignment had deeper understanding for the subject and scored better in the homework questions. The motivation behind this analysis is to evaluate the game's effectiveness and assess its value in any given aspect of the topic. For this purpose, we show an example of how the increase in students' learning outcomes could be tested and how the effectiveness of certain game-aided pedagogy is evaluated. This concept will be applied in this project for the five developed modules.

In this example, we test the effect of the game play in improving students' scores in the two questions shown below:

Question 1: *From your lecture notes, The D-CS system minimizes the number of vehicles caught in the dilemma zone at the onset of yellow by extending the green phase as long as vehicles exist in the dilemma zone. What could the limitations of the D-CS be? i.e., what would limit the effectiveness of the D-CS?*

Question 2: *Assume that a D-CS system is being implemented in two sites* ***having the same average traffic volume****. In one site, the D-CS is very effective and is catching zero vehicles in dilemma zone per hour. In the other site, the system can rarely find a time when there are zero vehicles in dilemma zone to end the phase. What could the reason be?*

Table 3 shows the statistical analysis of the students' score in the two questions by group and game total (GT) score (and the statistical interaction term). It can be seen in the table that there was a significant difference in the results by group for the first question only. Although there was a difference in performance in question 2, it was not statistically significant. Group 1 (students who played the game before solving the homework) scored better because they had better in-depth understanding of different traffic stream characteristics and the capabilities and limitations of the D-CS. However, the statistical results reveal that the HW questions and game play were not necessarily designed to work in tandem in this particular case. Question 1 quotes the D-CS objectives from lecture notes, and then asks the students to infer its possible limitations, which could either be stipulated or observed during game play. Some of the students who played the game first had a better chance of observing these limitations. The answer to question 2 had to do with the "platooning" phenomenon in some sites that could present enough traffic gap for the D-CS to work effectively, even with the same average traffic volume. However, although the game play scenarios showed cases with platooning and cases without platooning effects, no verbal description of these cases was provided and no appropriate scoring rubric was designed for the grader to measure the subtlety of possible answers to this question. This in fact illustrates the importance of integrating the development of learning objectives, game play, and assessment tools. We describe how to improve the game and associated tools to increase learning in the critical assessment and proposed game redesign section.

Table 3. Statistical Analysis of Students' Scores

Homework Question	**Source**	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
1	Group	1	2.19	2.19	7.02	**0.03**
	GT	1	0.02	0.02	0.08	0.79
	GT*Group	1	0.01	0.01	0.01	0.96
2	Group	1	0.01	0.01	0.02	**0.88**

	GT	1	0.01	0.01	0.01	0.92
	GT*Group	1	0.32	0.32	0.52	0.49

Insights gained from a students' focus group

We have also conducted a student focus group at the end of the semester to hear feedback from students. Regarding the assessment protocols, students indicated that the number of surveys conducted during playing the games should be reduced, and that students should be asked to stay in the class after the lecture for long enough time to complete the surveys thoroughly. They stated that the game was relevant to learning in general in the course, which was good. Compared to a "virtual stock exchange" game they played in another engineering course, this one was "very relevant to the class," and they were more motivated to do the homework associated with the course module. One student inferred that game modules dealing with more complicated subjects would be even more effective, and stated that this game would be very useful in an introductory course on Transportation Engineering.

III. Research Objectives and the Cyclic Model

The overall goal of this project is to improve students' learning outcomes and engagement in transportation engineering. There are two major objectives:

1. Develop five interactive learning tools for CEE-Transportation courses that are common to almost all CEE-Transportation college programs.

2. Develop associated instructional tools, including assignments and assessment tools, that shows impact of multimodal (traditional mixed with new media tool) teaching on learning gains and motivation.

Table 4 shows how these objectives are mapped into the cyclic model.

Table 4. Goals and objectives based on Cyclic Model

New Learning Materials and Teaching Strategies

- Develop online games that supplement traditional instruction in Transportation Engineering courses.

- Develop course modules that can be used in high school driver's education programs to simultaneously promote safe driving behavior and engineering as a potential career. *(Advisory board members will provide guidance throughout development and serve as a group of potential early adopters, and we will work with the local public school system)*

Develop Faculty Expertise

- Develop materials that explain benefits of learning through multiple methods (i.e., traditional lectures combined with games).
- Demonstrate materials and teaching methods at workshops to help instructors use multiple teaching methods.
- Establish an online distribution site that includes a discussion forum for sharing classroom experiences.

Implement Educational Innovations

- Integrate online games into traditional instruction in Transportation Engineering courses at home institution.
- Work with high school teachers to include course module in driver's education courses.
- Digitally disseminate game, course module, and assessment tools that Transportation Engineering faculty and high school teachers can use to teach and assess learning outcomes.

Assess Learning and Evaluate Innovations

- Collaborate with our advisory board to develop and evaluate game course modules.
- Evaluate college students' engagement in transportation engineering in relation to use of multiple teaching methods using motivational scale instrument.
- Assess college students' learning gains using performance assessment
- Assess changes in high school students' decision-making as a result of learning about the yellow light "dilemma zone" using game performance results.
- Conduct focus groups with advisory board members and students.

Conduct Research on STEM Teaching and Learning

- Publish tested models of workshops and course modules that help college faculty and students improve content knowledge.
- Use assessment results to describe impact of using multiple teaching methods to increase engagement in transportation engineering and engineering as a career for both college and high school students.
- Disseminate results through the Transportation Research Board conference and through engineering education conferences held by IEEE's Frontiers in Education and the American Society of Engineering Educators.

C. Critical Assessment and Future Work

Since the engagement assessment results showed that students self-reported gains in intrinsic motivation and identified regulation, we are encouraged that our game development is on the right track. However, to increase engagement in the learning technology and avoid the game shortcomings, we plan to:

- Integrate the game play with traditional teaching materials and HW questions/quizzes, and

- Increase the "competitiveness" factor by introducing a scoring mechanism that enables students to play against their own and other players' scores before knowing the final answer.

In order to fine-tune our assessment protocol, we will:

- Reduce the number of questionnaires

- Provide more time for students to complete the questionnaire, and

- Change the questionnaire prompt from the narrow topic of "signalized intersections" to module-related topics.

Finally, our plan for future work includes the development of revised learning objectives by interacting and soliciting input from our advisory group. During this step, we will clearly identify what difficulties the students are currently experiencing in the courses in which the games will be integrated, and determine the needed improvements and changes expected to occur with the introduction of the games. Assessment of the learning outcomes will be used to assess the game themselves, and subsequently result in improvement of the games and learning exercises themselves.

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