To Game or Not to Game

Teaching Transportation Planning with Board Games

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Traditional "chalk and talk" teaching in civil engineering is gradually being replaced with active learning that focuses on encouraging students to discover knowledge with innovative pedagogical methods and tools. One interesting such tool is the board game. This research examines the efficacy of adopting transportation board games as a tool in graduate-level transportation planning and transportation economics classes at the University of Minnesota from 2008 to 2011. The Department of Civil Engineering offered these courses with transportation board games on weekday nights. Students were asked to evaluate the effects of the games on their learning and to write self-reflective essays about their findings. The postgame survey revealed that the students' understanding of the planning process, network deployment, and practical issues, and their ability to form opinions about transportation planning had improved. Student essays on the game economy and its implications on planning further validated that the learning outcomes derived from this game process met the pedagogical goals. This analysis shows that students who are oriented toward learning more on the basis of the visual, sensing, active, or sequential learning styles, with all else being equal, tend to learn more effectively through this approach than those who do not share these learning styles. Overall, this research suggests that properly incorporating board games into the curriculum can enhance students' learning in transportation planning.

Students have different learning styles. Some students learn more by acting; others learn more by reflecting. Some learn by seeing; others learn by hearing. Some learn by sensing; others learn by intuition. Research has shown that most engineering students are visual, sensing, inductive, active, and some have global approaches. Traditional classroom teaching, however, often features an auditory, abstract, deductive, passive, and sequential "chalk and talk" procedure, which is contrary to the learning characteristics of such students (*1, 2*). This mismatch of teaching and learning styles may considerably lower students' interest in the subject and thus lead to inferior student performance. Fortunately, teaching in engineering education is currently undergoing a shift from focusing on conveying rote memory information and procedural knowledge to stimulating discovery by students and cultivating their problem-solving skills. To facilitate this shift, it is important to develop creative instructional methods and tools. Games and simulations offer two interesting tools.

Recently, instructors have begun to employ games and simulations for transportation engineering education because rules used in the games can be fun while also stimulating learning. Games and simulations, dubbed "experimental exercises," create active opportunities for students to "interact with a knowledge domain" (*3*). While many studies have examined simulation and computer-based game models in teaching engineering courses, board games have not been systematically applied and rigorously studied. In this research, from 2008 to 2011, the authors adopted transportation board games as an instructional tool in transportation courses (CE 5212/PA 5232 Transportation Policy, Planning, and Deployment and CE 8214 Transportation Economics) at the Civil Engineering Department of the University of Minnesota. In these courses, the design, planning, and deployment of transportation networks and the economics of network growth are integral parts of the curriculum, and such topics are embedded in the process of playing transportation board games. The hypothesis is that board games, by providing hands-on game experience for students as a network builder and operator, can improve their understanding of the economic foundation of transportation network growth and the decision-making process in transportation policy, deployment, and operations. The key research questions follow:

- Can board games improve the teaching in a transportation planning course?
- Why and how do board games enhance learning in transportation planning?
- What are the implications of the use of games in transportation planning education?

The next section reviews the literature on using games in teaching and is followed by a detailed description of the authors' research method that posits the connection of transportation board games and teaching transportation planning. The following section explains how the authors applied transportation board games in graduate-level transportation classes. The research findings are summarized in the following three sections, and the paper concludes with a summary of what was learned from this experiment as well as recommendations for future teaching practice.

LITERATURE REVIEW

Research has shown that people remember more when active rather than passive: they remember about 20% of what they hear (passive), 70% of what they say (active), and 90% of what they say and do (active) (*4*). Therefore, active learning, which encourages participation in the knowledge discovery process, can better promote students' interest and performance than can lecture-dominant teaching. The essential elements of active learning are student activity and engagement in the learning process (*5*). Games and simulations

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are examples of active learning, where students actively seek and process new information in the process of interacting with peers or computers.

Games and simulations have received attention in education since the 1950s. A "game" is typically defined as "any contest (play) among adversaries (players) operating under constraints (rules) for an objective (winning, victory, or pay-off)" (*6*). Simulation, often computer-based, imitates the key features of a real scenario for participants in a safe and cost-effective way. According to Gredler (*3*), games and simulations share the following features: (*a*) they bring the players to new scenarios, and (*b*) students control the process. These two features make games and simulations experimental exercises that engage students in learning by doing.

Games and simulations also have key differences (*3*). First, the purpose of a game is to win the competition, whereas the purpose of a simulation is frequently to finish a professional task (such as exploring the change of the network structure as demand varies) or fulfilling a professional role (such as controlling traffic lights). Second, the sequence of a game is linear, but the sequence of simulation is nonlinear. Third, the outcome of a game is determined by sets of rules, while the consequence of a simulation is shaped by the inherent casual relationships among variables and the interactions of the components in the simulator.

Games and simulations have been increasingly incorporated into teaching in civil engineering education and have been found to have positive effects on learning. For example, the University of Minnesota developed a suite of web-based simulation modules called Simulating Transportation for Realistic Engineering Education and Training (STREET) for undergraduate and graduate transportation courses in simulating the evolution of road network and land use, travel demand modeling, geometric design, traffic flow, and traffic signal control (website found at http://street.umn.edu). Research has evidenced that some of the modules (such as ADAM and SONG) can improve students' self-reported understanding of transportation planning, their ability to form opinions, and their skills in problem solving and decision making (*7–9*). Liao et al. (*10*) developed a traffic control simulator called Gridlock Buster to teach elementary school students the basics of traffic engineering in Minnesota. Their survey results disclosed strong interest by students in this tool and their acceptance of the traffic engineering curriculum. Ebner and Holzinger (*11*), in a graduate-level class on structural concrete, applied an online game called Internal Force Master, where students were given a set of problems to solve. In this game, points were accumulated by students, and those with high scores were listed. The postgame survey revealed that students were excited about this game and that the minimum learning results of playing the game were no less than from the traditional teaching methods. Kyte (*12*) developed a simulation module named Mobile Hands-On Traffic Signal Timing Project (MOST) for training courses on traffic signal timing, where student can practice implementing traffic signal operational parameters at both isolated sections and coordinated systems. In teaching high school students urban ecology, Gaudart (*13*) incorporated an epistemic game named Madison 2000, where students worked as urban planners to redesign State Street in Madison, Wisconsin. The game is described as a good instructional tool that adapts "authentic professionalism" in video game format (*13*).

However, the effects of games and simulation-based tools are still debated. On one hand, a number of empirical studies support their effectiveness. For example, consistent with the findings of some previously introduced studies, Whitehill and McDonald (*14*) and Ricci et al. (*15*) argued that games in teaching can contribute to improved learning. Gaudart (*13*) further showcased an example of simulation-based learning both as "an engaging activity" and "a compelling learning environment." On the other hand, some other studies report mixed findings. For instance, Pierfy (*16*) investigated 22 research studies comparing simulation games with other types of teaching, and finds that three studies favored traditional teaching, three supported simulation game treatment, and the remaining 15 studies reveal no significant differences. This research, nevertheless, further suggested that simulation games have a greater impact (in a positive direction) on students' attitudes and opinions than do traditional methods (*16*).

Our review posits that games and simulations have great potential to enhance students' learning interests and outcomes. Yet it should be noted that the success of applying them in class rests not only on the fit of the games and simulators with the teaching content but also on the organization of the game and simulation activity and on the students' learning characteristics. In addition, while computer-based games are increasingly popular in engineering education, other forms of games, such as board games, have not yet been systematically applied and evaluated in transportation planning courses.

METHOD

This research applies transportation board games in transportation planning courses at the University of Minnesota. This section delves into the fit of the games with the topics, the organization of the activity, and the relationship between students' performance and their characteristics in a game environment.

Subjects

The subjects are students attending the transportation policy, planning, and deployment class (CE 5212/PA 5232, a course cross-listed between civil engineering and urban and regional planning) from 2008 to 2011 and the transportation economics class (CE 8214) at the University of Minnesota during 2010. Class size ranged from 10 to 25. Most of the students were graduate students in civil engineering or in the urban and regional planning program at the University of Minnesota, although some senior undergraduates and other majors, such as applied economics, were also represented. In each class, a weekday night was scheduled for playing board games. Figure 1 exhibits the photos of the students playing transportation board games.

Games

A typical transportation board game consists of a group of players who aim to build a transportation network. Players take turns pursuing profit maximization according to the incentives, disincentives, and constraints. During the courses, the instructor provided 11 transportation board games to the students. Of those games, the following are represented in the results summarized in this paper: Air Baron, Metro, Rail Tycoon, Empire Builder, China Rails, Rail Baron, and 1870. Each game can accommodate a group of two to six people. Students were asked to form teams based on their interest. Air Baron is an airline game; the rest are railroad games. Except for Air Baron and Metro, most of the games have an embedded node structure (grid or hexagonal) allowing for incremental network link construction and letting

(a) (b)

FIGURE 1 Game night at University of Minnesota: students playing (*a*) Metro game and (*b*) Empire Builder game.

the topology emerge from gameplay. Air Baron, Empire Builder, China Rails, and 1870 have additional events such as recessions, strikes, and weather challenges that serve as exogenous variables. 1870 even includes a stock market and the merging of corporations. Table 1 summarizes the basic characteristics of the games.

Air Baron is a game in which airlines vie for control of American cities and other major foreign hubs. Each player aims to build an airline empire by amassing market share and cash. In the beginning, players roll dice to determine the order of play, and one player is selected as the banker. In one's turn, a player determines whether to go in or out of fare war or whether to remain in the current status. The player can collect government contract money if applicable. Each player can buy a spoke, take loans, pay loan interest, or sell assets at half of their original prices. Once a fare war is activated, the profits of all routes are set to zero and players roll dice to take over individual spokes. In addition to fare wars, there are other events (on cards drawn by players) that will affect the player or all players: air crash, fuel crisis, and recession. The first person with the combined

TABLE 1 Games Used During Game Night

Name	Type	Model Scenario	Key Mechanisms	Winning Criteria	Exogenous Variables	Network Grid Given
Air Baron	Air	Early periods of the U.S. airline industry	Build airline networks	Maximum market share	Air crash, fuel crisis, stock market, and recession	No
Metro	Rail	Early period of Paris railroads	Build railroads	The player who builds the longest rail line	No	No
Rail Baron	Rail	Early period of U.S. railroads	Purchase existing railroads and deliver goods by rail	The first player returning home with no less than $20,000 cash	No	Yes
Rail Tycoon	Rail	U.S. railroad from 1830s	Build railroads and deliver goods	When cities have no more goods left, the player with the most victory points wins	No	Yes
Empire Builder	Rail	U.S. railroad history	Build railroads and deliver goods	The first player who connects six major cities and has $250 million cash	Half shipping rate, floods, derailments	Yes
China Rails	Rail	Early period of Chinese railroads	Build railroads and deliver goods	The first player who connects four major cities and has $250 million cash	Half shipping rate, floods, taxes, strikes	Yes
1870	Rail	Railroads in U.S. Trans-Mississippi area	Auction, stock exchange, operation of companies, corporate merging, build tracks, and run trains	When any player goes bankrupt or the bank runs out of money, the player with the greatest personal holdings wins	Stock market and companies merging	Yes

sum of market share and cash exceeding the winning target wins the game. Probably due to the existence of the stock market and financial system in the game, the students ranked it as the second most difficult game.

Metro is played on an empty square board consisting of small squares. Each player owns several metro stations on the fringes of the board at the beginning of the game. Players compete to make the longest metro lines, starting from their stations. In each player's turn, only one tile is allowed to build the line. The game ends when no new tiles can be placed on the board. The winner is the player with the highest scores. This game was rated as the simplest one of the games. This rating was probably because the railroad length and the number of connections to the city were the only two variables considered in the player's objective function.

The Rail Tycoon game models railroading in the eastern half of the United States. Before the game, each player randomly draws one card, which gives the player bonus victory points at the end of each game if the goal on the card is achieved. In the beginning of a turn, players participate in an auction to determine the first player of the turn. Players can perform the following actions during their turn: building tracks, urbanizing a city, upgrading engines for railroads, delivering goods, and building western links. When the cities have no more goods, the player with the highest victory points wins. This game was rated medium in difficulty. Players not only build tracks but also deliver goods. Compared with Air Baron and 1870, all the model's variables are endogenous (i.e., there are no factors related to the financial system or operations of the company).

Rail Baron is a game about assembling railroads. Unlike Rail Tycoon, the railroad network is given. In the beginning, each player decides his home city. A player's job is to purchase railroads (to save on shipping costs and earn revenue) and to deliver goods to the home city by rail. The first player with $200,000 when returning home wins. This is considered the second easiest game because the network structure is given (although the ownership of multiple lines by players creates many distinct routing patterns).

The Empire Builder game builds railroad tracks on a map of the United States, Canada, and Mexico, where players draw tracks with special wipe-off crayons. Before the game, one player is selected as banker and distributes $50 million to each player to start the game. Players compete to build rail tracks, upgrade trains, and deliver goods on trains. The winning player must meet two requirements: (*a*) seven major cities are connected with one continuous line of track, and (*b*) the player has at least $250 million in cash at the end of his or her turn. The rules of the China Rails game are similar to those of Empire Builder.

A variation of 18XX games, the 1870 game develops railroads in the Trans-Mississippi area. The game procedure consists of several stages: (*a*) In the beginning, players decide the order of play and receive initial funds (stock round); (*b*) Players operate the company in a stock market, where buying a private company is allowed (operation round); and (*c*) The game process includes eight stages to simulate the evolution of train engines (game process). The ending point of a game is when any player goes bankrupt or the bank runs out of money. This game was ranked as the most difficult.

Courses

The two courses where board games are applied are Transportation Policy, Planning, and Deployment (CE 5212/PA 5232) and Transportation Economics (CE 8214). The goal of CE 5212 is to help students learn essential concepts, facts, and case studies in the development of transportation policy, analysis of transportation plans, and the deployment of transportation technologies and plans. CE 8214 teaches theories and applications of transportation economics to help inform the real decisions that are made in practice. Both courses cover the economics and agents of road network growth. The abstract concepts in these topics, such as equilibrium and evolution, can be elucidated through the process of building artifacts of a transportation network in a board game environment.

It is hypothesized that appropriate transportation board games can help students understand these important transportation network concepts. By participating in board games, students act as self-interested network builders. They are advised not to focus on who wins but on why one wins and what the implications on actual planning and network growth are. Through active participation, students are expected to learn from the network building process.

Learning Styles

On the basis of Jung's theory of psychological types (*17*), students' learning styles can be grouped into five categories: perception, input, organization, processing, and understanding (*1*). Table 2 shows the blend of learning styles and their corresponding teaching styles. Based on this table, instructors can choose different teaching styles to maximize the learning potential for all students. For example, engineering students are generally described as having learning styles that emphasize visual, sensing, inductive, active, and global reasoning. Thus, the favorable teaching style should be abstract in content, visual in presentation, active in student perception, and global in perspective.

Board games seem a good fit for this class because they underscore the active participatory process where students apply visual, sensory, and sequential learning styles. Focusing on the global learning style, the instructor introduced the goals and oriented the students in learning before the game. Next students signed up for the game they chose to play. A signup list was posted, and undergraduates, planners, and engineering graduate students signed up in turn. The rules were that they could not sign up for a game that was full and could not choose a game that had more than one of their group signed up, unless all games had already been chosen by one of their group. Thus students were distributed across games to ensure that each game had a mix of students of different backgrounds. Students

TABLE 2 Corresponding Learning and Teaching Styles (*1*)

Learning Style	Reasoning Preference	Teaching Style	Emphasis
Sensory–intuitive	Perception	Concrete–abstract	Content
Visual–auditory	Input	Visual–verbal	Presentation
Inductive–deductive	Organization	Inductive–deductive	Organization
Active–reflective	Processing	Active–passive	Student participation
Sequential–global	Understanding	Sequential–global	Perspective

TABLE 3 Game Night and Learning Styles

Stage	Procedure	Learning Style
1	Instructor introduces goals and assignments and asks students to fill out pregame survey.	Global
2	Students study the instruction manual of chosen game and decide when to finish game.	Active
3	After game, students fill out postgame survey and write reflective paper.	Inductive

were given access to the game rules so that they could read them in advance. The games typically have more complicated rules than popular board games such as Monopoly, in which the network, a simple path, is already preconstructed. It is a given that game play could take a long time to establish a victor, especially with the unfamiliarity of players with the rules and strategies. Sometimes it can take four to five hours to naturally end a game.

Purposes and Procedure

The goals of the game night are to help students understand the impact of the interactions of stakeholders on network growth and grasp the underlying economic principles of networks. For example, how does the game economy work from the perspective of supply, demand, exchange of goods, and competition, and what are the incentives and disincentives for network expansion? To elaborate, as a game player, a student has the opportunity to examine strategically not only how to maximize the profits from network construction and goods delivery, but also how to compete and cooperate with other investors to win the game.

The game night class begins with each student being asked to fill out a pregame survey about his or her academic background. Then, the instructor overviews the goals of the class and introduces the assignment. Each group of players gets to decide how long they want to play the game (a minimum of 2 h and as many as 5 h have been chosen). After the game, each student is asked to fill out a postgame survey and to write an essay to summarize his or her findings from the game. The teaching procedure and learning styles of students in each stage are depicted in Table 3.

SURVEYS

Pregame Survey

The pregame survey yields information, which is tabulated in Tables 4 and 5, about the academic backgrounds and learning styles of the students. The average age of students was 25. About 76% of the students were male, and the average number of years spent working in transportation was 0.62. More than 71% of the students expressed an interest in pursuing a transportation career.

About 8% of the students rated "sensing" high as one of their learning styles, and about 37% rated it as moderate. More than 70% of the students chose "visual" as moderate or high in choosing a learning style. More than 56% of the students chose "active" as either moderate or high in describing their learning style. About 33% of the students chose either moderate or high for sequential learning style, and about 36% chose moderate or high for global learning style. The authors conclude that students in these classes tend to be oriented toward these learning styles: visual, sensing, active, and some sequential. About 96% of the students indicated more than one learning style.

TABLE 4 Pregame Survey Results

Category	Variable	Mean	SD	Minimum	Maximum
Demographics	Age (years)	25	3.4	21	38
	Gender	0.76	0.43	0 (female)	1 (male)
	Working experience (years)	0.62	0.49	0	1
Learning styles	Sensing	2.22	1.03	0	4
	Visual	3.02	0.98	0	4
	Active	2.38	1.22	0	4
	Sequential	1.96	1.02	0	4

NOTE: SD = standard deviation. Number of subjects = 50.

Postgame Survey

The postgame survey results are summarized in Table 6. On a scale from 0 to 4, students evaluated their scores on specific topics. The average score in enhanced learning experience reached 2.72 (at the 70th percentile). Scores in other fields (understanding of transportation planning, understanding of network deployment, improved ability

TABLE 5 Pregame Survey Results

Category	Variable	Frequency	Percentage
Learning preference	Concrete experience	16	16.67
	Reflective observation	27	28.13
	Abstract conceptualization	20	20.83
	Active experimentation	29	30.21
	NA	4	4.17
Innovative teaching strategies motivates me to learn	Strongly agree	6	11.53
	Agree	12	23.08
	Neutral	25	48.08
	Disagree	7	13.47
	Strongly disagree	2	3.85
Perception	Highly sensing	4	7.70
	Moderately sensing	19	36.54
	Mildly sensing or intuitive	14	26.92
	Moderately intuitive	13	25
	Highly intuitive	2	3.85
Input	Highly visual	18	34.6
	Moderately visual	20	38.5
	Mildly visual or verbal	9	17.3
	Moderately verbal	4	7.69
	Highly verbal	1	1.92
Processing	Highly active	9	17.65
	Moderately active	20	39.21
	Mildly active or reflective	7	13.73
	Moderately reflective	12	23.53
	Highly reflective	3	5.88
Understanding	Highly sequential	3	5.88
	Moderately sequential	14	27.45
	Mildly sequential or global	15	29.41
	Moderately global	17	33.33
	Highly global	2	3.92

NOTE: Number of subjects = 50; NA = not available.

TABLE 6 Postgame Survey Results

Variable	Mean	SD	Min.	Max.
Easiness (the greater the value, the easier)	4.20	1.81	1	9
Satisfaction (the greater the value, the more satisfying)	5.76	1.95	2	9
Stimulation (the greater the value, the more stimulating)	6.18	1.71	1	9
Enhanced learning experience	2.72	1.07	0	4
Improved understanding of transportation planning	2.70	0.89	0	4
Improved understanding of network deployment	2.94	0.91	1	4
Improved ability to form opinions on transportation planning	2.58	0.99	0	4
Improved understanding of practical issues in planning	2.76	1.00	0	4
Effectiveness of board games as a teaching tool	2.88	0.84	1	4
Overall learning experience	2.91	0.81	1	4

NOTE: min. = minimum, max. = maximum.

to form opinions regarding planning and deployment issues, understanding of practical issues associated with planning and deployment, overall learning experience, effectiveness of a board game as a curriculum tool) are all above 2.5 (at the 60th percentile). The results posit that transportation board games are an effective tool in assisting students' learning in transportation planning.

Figure 2 shows students' evaluations on the degree of ease, satisfaction, and stimulation of the games they played. The game Metro is ranked easiest, and 1870 hardest, with China Rails and Empire Builder in the middle. In terms of satisfaction, Rail Baron, China Rails, and Metro rank as the top three. Ranked for the degree of stimulation, the game choices were (first tier) Metro and Rail Baron (6 points out of 9) and (second tier) Empire Builder, China Rails, and Rail Tycoon. Overall, Rail Tycoon, China Rails, and Empire Builder showed a good balance of ease, satisfaction, and stimulation.

QUANTITATIVE ANALYSIS

To analyze the effectiveness of board games for students with different learning styles, the students are first categorized into two groups, based on their learning style: students who self-identify as SVAS (either sensing, visual, active, or sequential) and students who choose none of these learning styles. In the survey, if one checks

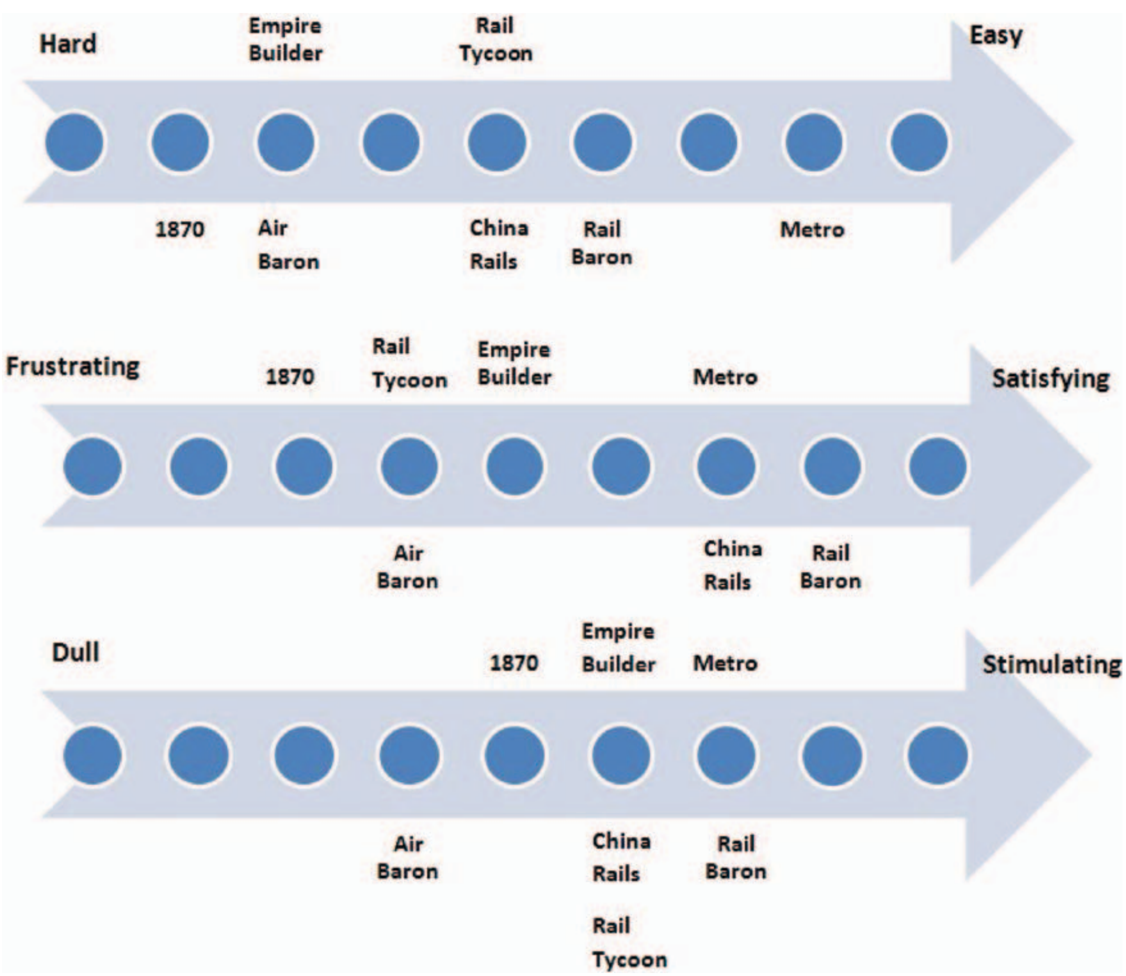

FIGURE 2 Student evaluation of board games.

TABLE 7 Effects of Different Learning Styles on Self-Evaluated Performance

Independent Variable	Coefficient	SD
SVAS group[a]	0.38**	0.16
Stimulation	0.09***	0.03
Easiness	0.01	0.03
Satisfaction	–0.02	0.03
Number of learning styles	0.03	0.04
Age	0.02	0.01
Male	0.14	0.11
Graduate student	0.06	0.11

NOTE: Number of subjects = 50; dependent variable = log (sum of efficacy scores). Efficacy score = learning + improved understanding + overall learning experience + knowledge on network deployment + forming opinions on transportation planning + effectiveness of board games as teaching tool.
[a]SVAS group = students either highly or moderately visual, highly or moderately sensing, highly or moderately active, or highly or moderately sequential in learning style.
*$p < .05$; **$p < .01$; ***$p < .001$.

TABLE 8 Correlation Tests of Learning Styles

	Visual	Sensing	Active	Sequential
Visual	1	0.20	0.24*	0.10
Sensing	0.20	1	0.37**	0.30*
Active	0.24*	0.37**	1	0.09
Sequential	0.10	0.30*	0.09	1

*$p < .05$; **$p < .01$; ***$p < .001$.

highly sensing or moderately sensing, one is categorized as sensing and assigned the value of 1; otherwise, one is considered as intuitive and assigned the value of 0. The dependent variable is the log sum of the seven effectiveness measures (enhancing learning, improving understanding of transportation planning, effectiveness of board games as a teaching tool, learning experience, knowledge of network deployment, forming opinions on planning, and understanding of practical issues). The independent variables include students' groups based on learning style, students' demographic information, and the characteristics of the games (degrees of ease, satisfaction, and stimulation).

The statistical results are shown in Table 7. Two variables are statistically significant at the 10% level. One is the coefficient (0.38) of the SVAS group, signifying that a student who is either oriented toward one of the learning styles of sensing, visual, active, or sequential tends to evaluate the learning outcomes about 38% higher than a student who did not choose these learning styles. Also statistically significant is the stimulation variable. The coefficient indicates that a more stimulating game is associated with an elevated student self-evaluation of the learning performance by approximately 9%. The differences in the level of easiness and satisfaction of board games do not have a statistically significant effect on the outcome. The difference in students' demographic information does not impact the learning outcome with enough statistical significance. The correlation test of students' learning styles reveals that some learning styles (such as active and sensing) are correlated (Table 8).

QUALITATIVE MEASURES

In addition to the self-evaluated scores, students were asked to summarize their learning from the games in essays, in which they were to particularly focus on the demand, supply, incentives, and disincentives of network growth. First, the students diagnosed the incentives for players. One student who played the China Rails game wrote: "Incentives for players include building railways and connections to cities that have the potential for the highest use. . . . Other incentives include the commission on commodities that are presented on load cards. Commodities such as jade and oranges yield higher commissions in certain regions than say tourists or oil in other parts of China. These commissions provide incentives for players to construct railways to certain areas, depending on potential commissions."

One student who played the Empire Builder game identified the clustering of networks in one region: "There was a strong incentive to not only build in increments but build in a region of the country. Players would build routes to all the cities in a region to hold control over those cities. If a player started building in the north, there would be incentives to stay in the north. . . . There was also an incentive to build in the east part of the map. The incentive in the game was to build a railroad empire in the east and expand the lines to the west when the resources and demands were present to do so."

After the Railway Tycoon game, one student noted ". . . if cities were not urbanized, there was a disincentive to build links to these cities." These findings suggest the impact of land use (accessibility) on transportation. In other words, networks are built to increase access to goods and services, where regions that are closer and have higher potential for improving accessibility are more likely to be connected.

Second, the students further pinpointed many disincentives in the games. In the Empire Builder game, for example, one incentive is the high cost to build networks that calls for a balance between constructing networks and delivering goods. Therefore, there is a disincentive to "build long railways because it would be costly up front." Another key disincentive is the operations cost. While there is an incentive for a train to be full to maximize profits, that also creates a disincentive in that the train cannot pick up very valuable cargo along the way. Players have a delicate balancing conundrum between how much to ship from the origination and how much to pick up along the way—a tradeoff similar to that in the adage, "A bird in the hand is worth two in the bush." In terms of observing the phase changes of network change, one student who played the Rail Baron game argued that the game "showed slow initial growth while resources were developing, rapid economic growth when the potential existed for it, and slower operations during the maturity phase. It demonstrated the mergers and acquisitions characteristic of railroads in the twentieth century; furthermore, many strategies in the game correspond to actual business approaches." This observation matches the life-cycle theory of network development taught in both classes. It indicates that by using simplified board games, students can learn this theory through hands-on experience and inductive learning style.

Third, many students compared the network growth in the game with real transportation experiences. For instance, in reflecting on the Metro game, which builds subway networks in Paris, one student wrote, "The game models transportation system development in Paris in the 19th century; i.e., the Paris Metro. The actual

Paris Metro spent years in dispute and disagreement over where to build the first subway tunnels. The game of Metro, with its rules restricting how a card may be laid as a tunnel connection, in some ways mimics the complexity that the early planners, engineers, and developers experienced when committing to build the first tunnel connections under Paris."

Of course, the game model is much simpler than the actual. Many students also identified the mismatch of the game with reality. Following are a few examples:

- Timing of delivering goods. "In reality, few–if any–rail roads were actually built on a pay-as-you-go financing model, and many major lines found themselves in bankruptcy soon after completion." (China Rails)
- Operational model. (*a*) "[In the game] each player can only operate one train. In the real word, once a network is built and its capital cost paid and accounted for, there are returns to density." (*b*) "One significant omission from the game is operating cost. This distorts economics analyses that players make each turn, somewhat, because an operating charge would lead players to favor destinations reachable in fewer turns." (Empire Builder)
- Limited origins and destinations. "All loads can only be picked up and dropped off in cities. In fact, before automobiles and trucks became common, railroads were generally the only viable way to move farm and other rural goods to market in the cities." (China Rails)

The above synthesis of students' findings indicates that they have gained deeper understanding of the economic foundation of transportation networks. Their reflections considered the roles that supply, demand, constraints, competition, and cooperation play in the system, thereby achieving the pedagogical goals of applying board games.

DISCUSSION AND CONCLUSIONS

An effort to match the teaching style with learning styles of engineering students, this research applies transportation board games as a pedagogical tool in transportation planning and transportation economics courses. Transportation board games have two important features as a useful pedagogical tool. The first feature is in matching students' learning styles. Most engineering students are said to be more oriented toward learning based on the visual, sensing, inductive, and active learning style, according to Felder and Silverman (*1*). And transportation board games, underlying active participation, enable students to apply the above-named learning styles in a game environment. The second feature is seen in scenario matching. The transportation board games feature a bottom-up process of building transportation networks, which is consistent with the mechanism of network growth. Research has shown that even without a centralized planner, transportation networks can self-organize into hierarchies (*18, 19*). Transportation board games provide a simplified yet characteristic scenario for students to replicate the growth of transportation networks in their early stages. Therefore, the two features of transportation board games, matching students' learning style and transportation network growth, have motivated this research.

The survey results corroborate the authors' hypotheses about using board games in teaching. First, most of the students tend to be more oriented toward learning based on the visual, sensing, active, or sequential learning styles, with more than one third of the students identifying themselves as relying on the sequential style. In terms of learning preference, active experimentation ranks at the top, followed by reflective thinking, abstract conceptualization, and concrete experience. Further, the majority of the students indicate multiple learning styles. Correlation tests of these learning styles suggests that they are correlated for the students, which may be due to the homogeneity of the students taking this class. Second, the quantitative analysis shows that students who are either moderately or highly identified with the visual, active, or sequential learning styles, with all else being equal, have higher evaluation scores on the effectiveness of board game than do those who are not so identified. The authors believe this outcome is because students possessing these learning styles can more easily adapt to the game environment and therefore are better at learning by doing. Third, students' reflective papers about their game experience reveal that the learning outcomes achieve the goals of teaching: understanding the game economy (supply, demand, exchange, and competition), incentives, disincentives, and the implications on transportation planning.

Board games are not without limitations. In the postgame survey, one student indicated that the game played was too slow and "thus became a little dull after some time." Using a game that is faster to end is suggested. Another student expressed that "the learning curve is so steep that not all of the benefits can be achieved." Indeed, for difficult board games (such as the 18XX series), students need to spend more time studying the rules. Therefore, a brief introduction about the rules for the difficult games and giving guidance on the game process beforehand can be beneficial. Another student shared the thought that having a discussion before the games about the principles and key concepts in the games (such as land acquisition, early revenue streams, and debt leverage) may further enhance students' learning outcomes. This adjustment (for example, teaching related concepts and concepts in prior classes) may help reinforce students' learning and facilitate the game process.

Overall, this paper documents new efforts in teaching transportation planning by using board games. As with other interesting pedagogical tools, transportation board games in the teaching process aim to match engineering students' learning styles and to encourage active learning. The results illustrate that transportation board games can serve as a useful tool in transportation planning education. The authors recommend Rail Tycoon, Empire Builder, and China Rails, which keep appropriate levels of ease, satisfaction, and stimulation. They are suitable for open-ended subjects such as transportation planning, policy, economics, deployment, and evaluation. Goals and rules of the games should be clearly stated before the game, and a debriefing activity would be a beneficial complement. In addition, instructors should sufficiently consider students' learning characteristics to maximize their learning outcomes.

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