Getting to the Next Stop: Teaching Transportation Engineering through a Multilingual Board Game

G. R. Marvez, Tufts University Center for Engineering Education and Outreach

Marvez is a PhD student in the joint STEM Education and Cognitive Sciences program at Tufts University interested in games, language, and controversial discussions. In past research projects, they have worked on the development of virtual simulations for teachers to practice leading controversial discussions. They are interested in ways to prepare teachers to facilitate controversial debates with students in STEM classrooms, such as through simulations and games, on topics such as genetic modification, climate change, and public infrastructure. Marvez has also worked on the development of natural language processing models for assessment and personalized feedback in educational settings. At Tufts, Marvez works with McDonnell Family Assistant Professor Greses Pérez in the CEEO on the development of engineering board games for multilingual students in culturally relevant contexts.

Greses Perez, Tufts University

Greses Pérez is an engineer, learning scientist and educator. She received her Ph.D. in Science Education with a focus on Learning Sciences and Technology Design from Stanford University. Her scholarship specializes in the interdisciplinary study of language and cognition for students who experience a cultural and linguistic mismatch between the practices of their communities and those in engineering and science. In addition to her work on culturally relevant learning through emerging technologies, Greses uses mixed methodologies to investigate the strengths multicompetent individuals, whose lives exist between languages and/or cultures, might be able to contribute to the social fabric. Her mission is to expand who is heard and can contribute to the disciplines as society demands professionals with backgrounds as diverse as the challenges we face.

Greses' scholarship advocates to include the rich trove of insights from multicompetent groups in creating engineering solutions and scientific ideas. Before her time at Stanford, she was a bilingual educator at low-income elementary schools in Texas. As a civil engineer, Greses led EU funded projects in the Caribbean to create educational opportunities for coffee farmers and their families. She holds a B.S. in Civil Engineering from Santo Domingo Technological Institute, a M.Eng. in Civil Engineering from the University of Puerto Rico at Mayagüez, and a M.Ed. in School Leadership from Southern Methodist University.

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Introduction

Serious games are a category of games that are often used in education to provide access to complex systems. In past research and curriculum development, engineering teachers have implemented curriculum around STEM-focused games [1], such as for urban planning [2], transportation engineering [1], chemistry education [3] and computational thinking [4]. Due to the increased interactive engagement of games compared to lecture [5], [6], [7], engineering educators have utilized games to positively impact students' learning. However, these educational games are often only available in English. Students whose first language (L1) is not English may be limited in how they present their ideas to peers in these playful spaces, even though non-educational games have long been considered a space for language sharing and exploration [8]. Bridging the ways of speaking and knowing of students (and their communities) with science and engineering give learners access to associated disciplinary cognitive resources [9]–[12] and incorporating language through games in engineering learning can open possibilities where students develop connections between technical and scientific competencies and their local contexts. This research explores the design of a learning game that focuses on a local engineering problem, public transportation, in a way that is accessible to students with different L1 skills.

In this Work in Progress paper (WIP), we describe the creation of a multilingual print-and-play board game, Next Stop, that centers players as transportation engineers and urban planners of the Massachusetts Bay Transit Authority (MBTA). We are working on the development of a version for K12 students more focused on collaborative engineering practices (e.g., transportation modeling where students simulate changing traffic flow caused by new bus routes) and a version for civil engineering undergraduates focused on more complex issues like inequity and elasticity of demand in transit (e.g., scheduling inequalities and quality of vehicles in predominantly Black and Brown communities). In this game, students must develop a train, bus, and ferry system that focuses on the needs of community members in the historically underserved East Boston community characterized by a culturally and linguistically diverse population, that is mostly Latine identifying [13]. Students will have the opportunity to engage in team-based engineering design practices by discussing, implementing, and adjusting a new transit solution based on passenger movements in the game. Together, students discuss the placement of new stations. Then as a team, they manage the flow of passengers with the goal of moving as many riders as possible to their destination before the game ends or the system becomes overcrowded. Additionally, we describe curriculum materials teachers can use in conjunction with the game to lead discussions with students about inequity in access to public transportation and imagined city futures. A link to download the print-and-play version of the game is available at the end of this paper.

Background

In the United States, the current number of dual-language learners (DLLs) is 5.1 million students or about 10.4% of the total student population [14]. Of these 5.1 million students, 75.7% of them are Spanish speakers [14]. In Massachusetts, the percentage of DLLs is 10.6% [14], and in the Boston Public School system, nearly one out of every three students is a DLL [15]. This population of students is likely undercounted and is only expected to grow in the coming years

[16]. Curriculum shifts will be needed to meet this population's needs, such as including practices like *translanguaging*, the practice of using multiple languages within the same utterance, and the cultivation of students' home languages in order to allow them to bring their full repertoire of skills to their learning [17].

In the United States, students whose L1 is not English often have their language skills viewed through a deficit lens [16], [18]. Educators may believe that students should learn English as fast as possible and leave their L1s at home. However, this neglects the cognitive benefits students can gain when they bring knowledge from their L1 to their academic pursuits [19]. Students' L1 provides a way for students to access information that is familiar to them and learning in their language shows that educational systems value the knowledge that students bring when they present their authentic self in safe classrooms. Especially in STEM classrooms, students who are not in dominant social categories may feel that they do not belong in engineering due to a lack of representation and support [20]. However, drawing on these students' funds of cultural knowledge can be a way to include them in engineering education practices. Specifically for teaching practices, Ladson-Billings [21] stresses the importance of educators learning *from* students to understand and incorporate their culture and worldview views into the classroom. For example, in an ethnographic study that focused on Latine youth who were learning English as a second language, students self-selected relevant community engineering problems to solve and researchers followed their progress through these projects [22]. The authors found that treating Latine students' funds of knowledge as assets in engineering practices can be a way to inform teachers' culturally responsive instructional methods and to encourage students to consider thinking about themselves as engineers [22].

Learning about community-relevant, complex engineering problems is elevated when students get to engage with the work through their own problem solving and preferred language. The idea that students bring valuable experiences to their education when classrooms include their identities in a positive light informs our inclusion of relevant maps of communities, playable characters, local MBTA related events, and different languages that are important to students in our game design. We believe that games can provide a playful entry point to working with complex concepts and systems to a growing population of multilingual students in an accessible and meaningful format.

City planning and public transportation engineering are relevant complex engineering problems that the young people of Boston face every day. Serious games can supply a way to model these challenges. Currently, the City of Boston is redesigning its public transit system, the MBTA, to develop more frequent bus service in more areas of the city to better meet the needs of historically underserviced communities [23]. This redesign of the bus network will provide an opportunity for young people to analyze the ideas that go into transportation engineering and to imagine a future in which their local transportation options best serve them in their communities. Taking inspiration from games such as *SimCity*, *Mini Motorways*, and *Mini Metro*, we have designed a cooperative game that allows students to step into the role of a transportation engineer and rethink what it would mean to design a public transit system that places its community first.

Methodology: Study and Game

Game Design

In the game, *Next Stop*, students collaboratively decide where bus stops, train stations, and ferry routes should run for East Boston as urban planners and engineers working for Boston's transit system. While this game model could work with a map of anywhere in Boston, we wanted to focus on designing a playful engineering experience specifically for the primarily Spanish-speaking community in East Boston as its residents heavily rely on public transportation. Under the MBTA's bus network redesign, this part of the city would gain one bus line that has buses every 15 minutes (currently there is only one bus in East Boston that comes at least every 15 minutes) and 20% more midday, evening, and weekend bus services [24]. This would connect 69,000 more residents to other areas in Boston with faster and more frequent bus service [24]. Students in East Boston will see their transit networks change within the next five years in ways that hopefully serve their communities better, making this a relevant space to build engaging engineering activities around.

Students play this game on a print-and-play board with a map of East Boston with common street intersections labeled and cards that describe the challenges the players must overcome in a blended English and Spanish format. We chose street names that students of East Boston would be familiar with, such as the intersection their school is on, to increase their immersion with the game board. In the event deck, players can pull passenger (cards that tell players to place passengers on the map, such as during rush hour), infrastructure (cards that allow players to add extra bus, train, or ferry stops or service), or disaster cards (cards with challenges that players have to work together to overcome, such as having to close down train lines temporarily for safety reasons). These event cards are based on real MBTA-related events to enhance the narrative aspect and real-world relation to the game. Players' character cards have special abilities that allow them to make modifications to the network to improve passenger transit times. We selected character names based on common names for residents of East Boston, so that players could feel a stronger sense of connection and ownership to their engineering roles.

Players first work together to decide where the "destinations" should be. These are locations on the board where the players think the most passengers would want to go, like the airport or a school. Players must come to a consensus before moving into the "system building phase." Then, they decide together where the bus stops, train stations, and ferry routes should run to get passengers to their destinations. There is a limited number of bus stops, train stations, ferry routes, and number of passengers that can be on any mode of transport at a single time, so students must carefully analyze how they could provide service to the entire map by considering these stipulations. When the players finish their debate and decide together where the stops should go, the game enters the "stress testing phase."

In this phase, players take turns drawing from the event deck and moving passengers through the city by having passengers ride public transit or walk. From the event deck, players can pull passenger, infrastructure, or disaster cards, all of which players must resolve immediately (Figure 1). Players then roll to move passengers and then advance buses and ferries forward one stop and trains two stops. Players can choose to wait out the issue, which risks overloading the system, or use their characters' special abilities to resolve the issue faster, but this comes with having to use a turn solving the problem. Throughout the stress testing phase, players can see

how their network design performs under the strain of many passengers. Too many passengers waiting for transit and it is game over. By moving enough passengers to their destinations, players win the game.

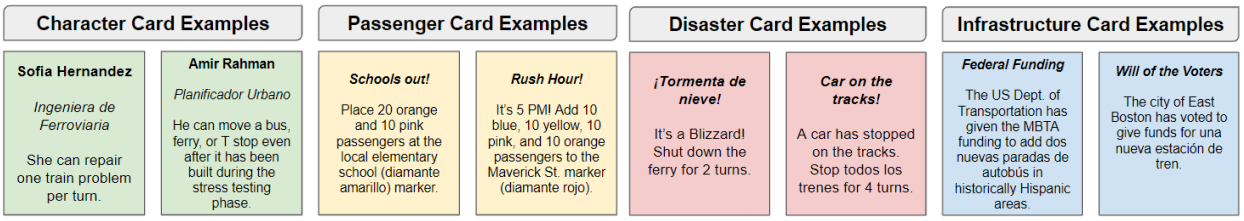

Figure 1. Bilingual examples of character and event cards.

Through this experience, students' learning goal is to become familiar with the complexity of public transportation systems and be able to think of themselves as an engineer who can analyze, model, and think critically about local engineering challenges. This game is also heavily based around discussions so that students may engage in debates about their solutions to the transit issues in East Boston just like real-life engineers could.

Curriculum Materials Design

As we do not want *Next Stop* to be a standalone experience for students, we are also designing curriculum materials for teachers to facilitate conversations about inequities in access to public transportation. In Boston, research has shown that those who live in predominantly White neighborhoods have shorter, faster commutes than those who live in African American neighborhoods [25]. And for those in certain low-income Latine communities in Massachusetts, public transit options "simply do not exist" [26]. These issues are an excellent place for teachers to lead students in conversations about what an equitable imagined future of the MBTA system would look like.

To address this concern, we are developing pre-game and debrief activities for teachers to run with students outside of the game. Before playing the game, teachers can introduce an activity called *Perfect Commute Time*. In this activity, students take maps of the city of Boston and draw out their commutes, discussing the differences in access to public transportation options and how long or difficult their commutes are. After this discussion, students redraw their commute maps to represent their ideal bus or train routes and discuss what it would mean for them and their communities if that transit option existed in real life. This also provides an opportunity for the teacher to cover topics that may be useful to students in playing the game, such as differences in access to transit and how this affects people's ability to get to work, school, and even grocery stores. Then, after students played the game, teachers can facilitate a discussion about the choices students made about where they chose to place transit stops and how their choices may be different from reality. Students can discuss what they would like to see in an ideal MBTA future and what problems currently exist in this complex system.

With these curriculum goals in mind, this game may work best in a classroom that includes social justice aspects of science and engineering education. Though not explicit in many STEM curricula, engineers design systems that have far-reaching societal effects. Designing instructional materials that consider the political effects of engineering in STEM education

encourages students who may become future engineers to think about ethical concerns in engineering early in their careers.

Design Implications

This game, with varying levels of complexity, is for students from the upper elementary to the undergraduate level. With younger age groups, the focus of the game is on collaborative efforts to redesign the transit system for their community and assessing their system. For older students, additional layers of complexity can be added, such as considering costs, timing of routes, and specific elements of equity like the differences in access between different racial and income groups in the city. Undergraduate courses in civil engineering or urban planning may be able to use this game design to prepare students to draft new designs of public transit systems, model complex engineering problems, and work on teams in this low-risk learning game. For these more advanced students, players will have to consider demands such as funding, elasticity of demand, and equity of access concerns for minority and low-income communities, based on their analysis of MBTA data on transit utilization [27].

We believe that providing an opportunity to solve community-relevant problems through play allows students the opportunity to choose to enact their knowledge in the language most familiar to them. This may increase these students' feeling of belonging and identity as an engineer or someone capable of discussing and solving complex problems that are relevant to their communities. While translating a game from English into another language allows more students to play it, it does not allow students of different language backgrounds to play together, and is the main reason why we focused on the development of blended game materials. For cards with Spanish instructions that English-only speakers may not know, Spanish-speaking players will be able to provide translation help and vice versa. Separate game rules in English or Spanish only would not allow students to truly work together across different languages and cultures.
As this game is still a work in progress, some of the mechanics may change, but the overall idea of solving local relevant transportation engineering challenges will remain the core of the game's development.

Planned Analysis and Anticipated Findings

After the final development of this game, we intend to use the game to provide an opportunity for bilingual students to engage on topics of community-centered transportation systems and equity in mass transit. We also are interested in the following research questions across different educational environments from upper elementary classes to undergraduate engineering programs.

RQ1: How can engineering learning environments reflect students' lived experiences?
RQ2: How can serious games like Next Stop provide an opportunity for students to experience complex transportation engineering and urban design collaborative problem solving?
RQ3: What is the role of playful experiences in engaging students into difficult conversations about complex engineering problems that affect their communities?

We intend to conduct interviews with bilingual students about their experiences with the game and how they identify as an engineer through self-efficacy STEM student measures [28]. These data sources will help us explore the ways that games can shift students into the mindset of an engineer and how best to meet the educational materials needs of multilingual students. We will

also video tape game sessions to analyze the players' discussions and decision making to examine whose ideas are taken up by the other students and why. From our early prototyping playtests of the game, we have seen that students have lively discussions about places of importance in their community and how the local transportation systems can better serve their communities. In further analysis of these in-game conversations, we will examine how these design discussions lead students to final conclusions about where bus and train routes should be built. We also are curious about the ways in which the new transit system model they co-construct in the game is different or similar to the transit network in reality. This can provide insight into how students picture an imagined future for transit in East Boston.

Conclusion and Future Work

The number of students whose L1 is not English will only get larger in the United States and the workforce will only get more diverse. Students deserve access to playful learning materials in their preferred languages and curriculum that connects them to their local communities throughout their educational careers. We believe that games are an avenue to meeting this goal.

Next Stop continues to be under development, but our early playtests with K12 and college students have shown that the concept of locally focused games excites students to think about how they would solve their communities' challenges. We plan to host the print-and-play versions of this game and curriculum materials for free on the lab's website and expand our offered languages to include other minority language populations in Boston, such as Portuguese, Cape Verdean Creole, and Mandarin Chinese. We hope that by offering multilingual opportunities to access complex engineering systems through play, students will see ways that they can affect their local community issues and exhibit changed mindsets about who can call themselves an engineer.

Supplementary Materials

The public version of the English/Spanish prototype of *Next Stop!* is available at this link: https://sites.tufts.edu/marvez/2022/12/13/next-stop-teaching-transit-engineering-through-board-games/

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