Interactive learning through gaming simulation in an integrated land use-transportation planning course

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Apart from changing the way the entire world lives and works, computers and technology have changed lecture rooms and teaching styles. In line with (unusual, but effective) trends at other universities, final-year civil engineering students at the University of Pretoria now play a simulation game, UPTown, much like SimCity, as part of the integrated land use-transportation planning module. UPTown was developed by the University.

The simulation game promotes active and social learning – the preferred style of learning of students these days – and allows them to explore and experience the problems they will encounter in the world of work. Assessment of student performance showed that the game significantly enhanced the achievement of learning outcomes.

The simulation game addressed an additional need – to integrate the practice of land use development and transportation planning in order to achieve more sustainable, livable and inclusive communities. This need has been investigated by many scholars (Levinson & Krizek, 2008; Handy et al., 2002). Civil engineering curriculums increasingly reflect this integration by including modules on land use and urban and regional planning (Lyles 1987; Khisty, 1987; Krizek & Levinson, 2005) in order to "contribute to the development of analytical, synthetic, and creative abilities of engineers" (Khisty, 1987:58).

There still seems to be some confusion on what the nature and content of a typical integrated planning module should be, in what is regarded as an already overloaded engineering curriculum. The integration of urban and regional planning with the engineering curriculum is hindered by epistemological differences between the disciplines: various authors have argued that civil engineers and planners are fundamentally different in terms of their preferred approach to knowledge, their personality traits, and even their values (Lyles, 1987).

Planning modules in the civil engineering curriculum thus need to be appropriately structured to elucidate the conceptual linkages between the engineering and planning disciplines and should be delivered using appropriate and innovative teaching methods that help bridge the epistemological gap between "social" planning and "technical" engineering.

Computer-based simulation is a promising tool to enhance classroom instruction (Zhu et al., 2011). The UPTown simulation game is designed to help students explore the links between infrastructure investment, land development, city efficiency and equity outcomes, by guiding the development of a hypothetical city over time. Its innovation lies in the way it asks students to simulate the decisions of both public sector planners and profit-seeking developers, and the interactions between them. This allows them to discover the value of collaboration and integration not only across professional disciplines, but also between the public and private sectors.

The need for new teaching methods

The changing abilities and preferences among students require teachers to adapt their teaching methods. Brown and Adler (2008) describe contemporary students as social learners, based on the premise that their "understanding of content is socially constructed through conversations about that content and through grounded interactions, especially with others, around problems or actions. The focus is not on what we are learning but on how we are learning" (Brown & Adler, 2008:3).

A number of teaching approaches have emerged in response to the changing needs of students. Among the most prominent is active learning – a generic approach seeking to engage students more actively in the classroom through activities such as reading, writing, discussion or problem-solving (Bonwell & Eison, 1991). Studies have shown that active learning approaches are generally preferred by students

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(Nirmalakhandan et al., 2007; Carpenter, 2006), and tend to lead to improved student learning and achievement (Nirmalakhandan et al., 2007; Light, n.d.). The simulation game described here has cooperative elements, as it organises students into groups simulating agents with different objectives that – as students discover while playing the game – are best met when aligned with those of other groups in a collaborative rather than a competitive fashion.

Gaming simulation as a learning tool

The land use-transportation simulation game, UPTown, has some features in common with the SimCity approach. The most notable is its objective of making a game out of a complex social system. The game simulates the evolution of spatial and economic systems, population dynamics, and transport and travel demand. It also allows players to influence (but not entirely control) the trajectory of the game through simulated interventions and makes use of attractive graphics and visuals for displaying output.

Embedding gaming simulation within an integrated land use-transportation planning curriculum

The game is designed to help students engage with the practical implications of many of the topics discussed in class. It is intended to train students to do the following:

- Understand the nature of the relationships between land development, travel demand and transport system performance.
- Critically examine the implications of various land use-transportation strategies (such as compact city, sprawl, or corridor development strategies) on city performance and quality-of-life criteria.
- Explain, based on own experience, the role of different role-players (private and public) in the spatial development process, and the nature of the relationships between them.
- Communicate effectively with other role-players via formal planning documents and informal discussion.

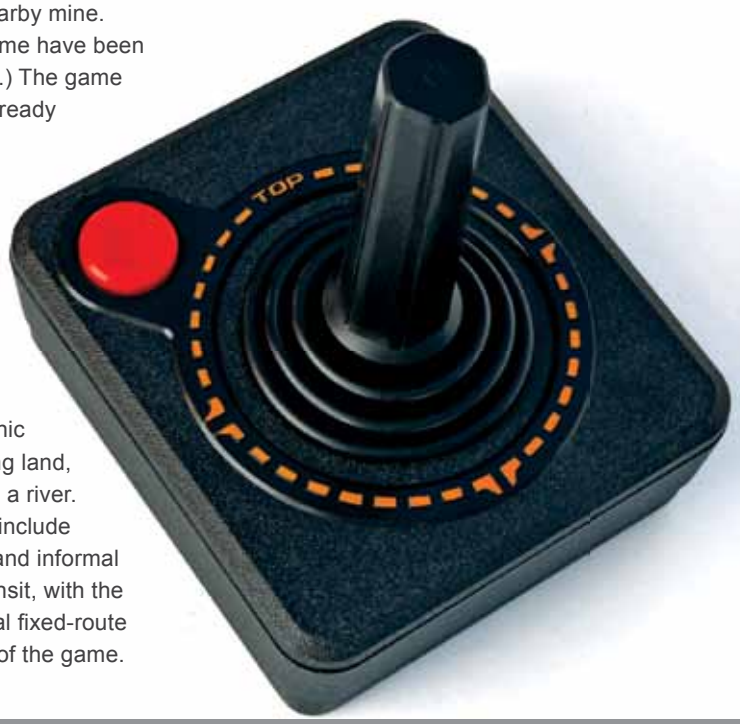
A key characteristic of the game is its orientation towards discovery. None of the outcomes listed above are spelled out in advance. Students are merely given the overall objective of the game – to facilitate the spatial and economic growth of a town over time within the constraints of the "action space" at their disposal (as public or private sector actors). They are then left to explore various strategies and relationships on their own. Feedback is provided to help students identify the positive and negative outcomes of their actions in order to develop their own understanding of these matters.

The UPTown game

The hypothetical setting chosen for the game is one typical of the South African development landscape, namely that of a mining town faced with high population growth due to the expansion of a nearby mine. (Variations on this theme have been added in recent years.) The game starts with the town already housing 60 000 people, with a rudimentary street network, and a large rural hinterland where future expansion may occur. Growth is constrained here and there by geographic barriers such as mining land, a mountain range and a river. Travel modes initially include walking, automobile, and informal (minibus-taxi) paratransit, with the option of adding formal fixed-route transit in later stages of the game. Both walking and taxi modes are used extensively, typical of travel patterns in developing countries. Each game is structured as an encounter between public sector planners, exercising control over both land use management and investment in the transportation network, and private sector real estate developers. Planners and developers both pursue the ultimate aim of accommodating as much growth as possible (in terms of population and employment, but not necessarily spatial footprint), as high growth levels are directly linked to the town's success as a vibrant and attractive community.

Planners and developers have different objectives and different means of pursuing them. For planners, success is measured by a number of objectives reflecting the general health of the city, such as the following:

- Sufficient land being available to accommodate housing and business growth
- Improving low-income workers' access to jobs (to reflect progressive social goals)
- Facilitating the efficient movement of people by finding a balance between sufficient investment in transport capacity (by highway and/or transit modes) and cost-effectiveness (thus avoiding over-investment) of the transport network



- Reducing the cost of living and vehicle emissions by containing growth in average trip distances

The game proceeds in three rounds, each representing a 10-year period, and each building on the previous round. Planners are thus forced to consider land use development and transport demand together. They are encouraged to start the game by developing a spatial development strategy for managing the growth of the town for the coming decade, to ensure the coordination of zoning and investment decisions.

Developers have the ultimate objective of maximising the profits derived from developing and selling or renting out building stock. The program simulates land values and construction costs based on the size, type and location of new development, and then calculates the developers' profits based on the amount of floor space that is actually occupied. Developers have to find a balance between developing sufficient floor space to accommodate all potential growth in households and businesses (so as not to constrain overall growth by a shortage of building stock), and keeping vacancies low (as vacant buildings reduce profits). There is no explicit budget constraint, but the last point acts as a penalty for over-development.

The actions of planners and developers affect each other in current and subsequent rounds of the game. The amount of floor space of any given type that developers can construct in a zone is constrained by zoning and maximum density specifications chosen by planners. The location decisions of developers affect the distribution and density of travel demand, and the need for planners to expand transport capacity in subsequent periods.

Cooperation and competition

It is this link between public sector planning and private sector investment decisions that gives the game its cooperative nature. Neither planners nor developers can control each other's actions. The actions of a third group of role-players – private households and businesses – are not controlled directly by either group, but simulated externally. A key feature of the game is that it takes the performance of both planners and developers into account when determining the overall performance score for the town. Each group thus benefits from the other group reaching its objectives. Objectives are structured so as not to be perfectly aligned – for instance, excessively sprawling development might reduce development costs (favouring developers), but decrease cost-effectiveness of road investments (penalising planners). This creates an incentive for groups to compromise and to coordinate their actions around a common vision for the area. Each game is played by six students divided into two groups: two students work together as developers and four as planners. The experience is competitive to the extent that students compete against one another in different games in order to emerge with the highest cumulative growth over three rounds of the game.

A key feature of the game is that it takes the performance of both planners and developers into account when determining overall performance.

Simulation engine

The behaviour of private role-players – households and businesses – and their impact on land use and travel are simulated off-line through a two-step simulation package developed specifically for this purpose.

Households are simulated in three income categories, each demanding different amounts of residential floor space.

Jobs are simulated as either basic (including manufacturing and mining industries) or retail (including commercial, office and public services).

Students do not have access to the simulator when making decisions, and only receive feedback on the success of their actions at the end of every round. The fact that the game is not as interactive as, for instance, SimCity, is intentional. The focus of the course is to allow students to explore and understand the substantive relationships underlying spatial and transport development, and not to run modelling software.

At the end of each round, participants in each game receive feedback in the form of a city scorecard, on which the performance of the city is scored against the objectives for each group. Typical scorecard indicators include the sufficiency of land and buildings made available for accommodating growth, profitability of development, cost-effectiveness of the road and transit networks, the reduction in congestion levels, containing growth in average trip distances and job accessibility for low-income residents. Scorecard scores contribute about 10% of student marks for the course.

Attainment of subject matter competence

Since the integrated course was a new one that incorporated the simulation game from the start, the opportunity was not available to test the impact of the simulation game objectively against a no-game control case. Two measures were considered to assess the effectiveness of the game to help students attain subject matter competence, namely scorecard scores and subjective ratings.

As a subjective measure of the effectiveness of the game as a teaching tool, students were asked to rate the extent to which the game contributed to their understanding of the integrated land use-transportation planning subject matter. Students' answers (summarised in Table 1) were generally positive, with an average score of 6.1 out of 9.

Table 1: Student assessment of simulation game (n=94)

Question	Number (percentage) of responses per category		
To what extent did the UPTown game contribute to your understanding of the infrastructure/ development planning process? (Scale: 1=no help, to 9=significant)	Poor contribution (rating = 1–3)	Average contribution (rating = 4–6)	Good contribution (rating = 7–9)
- Students playing planners	2 (3%)	27 (45%)	31 (52%)
- Students playing developers	0 (-)	22 (67%)	11 (33%)
How would you rate the contributions provided by various members of your group?	Everybody contributed equally	Unequal: some did less than others or nothing	One person did all the work
	55 (59%)	38 (41%)	0 (-)

In general, students performed better, and developed a better grasp of the material when faced with more complex analytical tasks and more "degrees of freedom" in terms of the set of actions they can take to reach their objectives.

Outcomes

The UPTown game is structured to allow students to explore aspects of the land use-transportation relationship in a hypothetical setting, while practising to work on complex problems in a collaborative teamwork environment.

Self-assessments of student performance showed that the game contributed to their ability to master the course matter. Students who faced more complex tasks (planners, as opposed to private sector developers) performed better, and reached higher levels of competence earlier on in the game. Grappling with complexity and a larger action space seems to lead to a better grasp of the material, and better achievement of the learning outcomes.

The game's key innovation over existing urban simulation software is particularly useful as a learning strategy, as it allows students to experience the benefit of collaboration. In the process, they learn syncretic thinking, clear communication and compromise. Some improvements can be made to the game to enhance its usefulness as a learning experience.

The first is to rotate students to be both planners and developers. This will give all students the opportunity to grapple with the issues faced by public and private sector agents. This would probably help equalise the achievement of competence across the class. Some students expressed a need for greater guidance and more extensive feedback. Some students lacked the skill to identify causal relationships between their own decisions and actions (as planners or developers) and the subsequent performance of their town.

While it is important to preserve the self-guided exploratory character of the game, it might be useful to spend more time modelling critical analysis and problem-solving skills for such students early on in the game. Lastly, the simulation engine needs to be migrated to an open-source platform to make it directly available to educators at other institutions.

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