A Virtual City Environment for Engineering Problem Based Learning

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Abstract. Secondary education students often struggle with Mathematics and Science, preventing them to follow a successful career in Engineering. At a higher education level, problems still exist, including in their motivation levels. A Problem-Based Learning approach can offer an interesting solution to help circumvent this issue by creating an environment in which the learners themselves seek out information and create strategies to solve the training situation. This present work, named project eCity, aims at creating a Virtual Learning Environment platform in the form of a city building simulator, in which students, often digital native, will feel at ease and encouraged to solve the practical engineering scenarios they will face. The eCity platform targets at the same time students from the secondary education and students from higher education, allowing them to work together in a close relation to solve the presented problems together.

Keywords: Engineering · Problem-based learning · Virtual environment · Serious games · Communities

1 Introduction

The difficulty that secondary education students have with Mathematics and other Science disciplines is a widespread problem in Europe as stated by several international comparative studies like PISA or TIMMS. This prevents these students from following a technical academic path like Engineering. And even when they do so, they still face a lot of problems on these disciplines at Higher Education level and become demotivated. This is not due to lesser skills of these students but mostly due to wrong educational strategies. We cannot forget that this generation is the "net-generation" or "digital natives": they are used to technology, they absorb information in shorter chunks, they expect instant responses and feedback, they want interactive and immersive forms of learning and they want to be active in their learning.

Problem-based learning (PBL) is a learner-centered pedagogy in which students are assessed on their ability to go through a problem solving process, usually based on real-life situations. In a convergent path, games and simulations can be instantiated for learning as they involve mental and physical stimulation and develop practical skills – they force the

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player to decide, to choose, to define priorities, to solve problems, etc. Games can also be social environments, sometimes involving large distributed communities. They imply self-learning abilities (players are often required to seek out information to master the game itself), allow transfer of learning from other realities and are inherently experiential with the engagement of multiple senses. Therefore, gaming and simulation environments are excellent learning tools because, through Virtual Environments, they can replicate real contexts or even provide training situations that occur in very specific circumstances while retaining the players' motivation to learn. Mixing PBL, games, simulations and virtual environments provides a Virtual Learning Environment (VLE) where digital natives feel comfortable because they are immersed in technology, they can communicate and they are active.

Engineering is one of the areas where PBL is a valid learning alternative/complement to the traditional methods. An engineer is a professional practitioner, concerned with applying scientific knowledge and innovation to develop solutions for technical problems. The work of engineers forms the link between scientific discoveries and their subsequent applications to human needs through new technological solutions. The responsibilities of the engineer may include defining problems, conducting and narrowing research, analyzing criteria, finding and analyzing solutions, and making decisions. Engineers must weigh different design choices on their merits and choose the solution that best matches the requirements. Their crucial and unique task is to identify, understand, and interpret the constraints on a design in order to produce a successful result.

Authors such as Woods [1] and Lacuesta et al. [2] confirmed in their studies the benefits of PBL for engineering students – considerable improvements in critical, lateral and creative thinking, problem solving strategies, intrinsic motivation, group collaboration, communication skills, entrepreneurship and collaboration with society and regional development. According to Kolmos [3] President of the European Society for Engineering Education, the implementation of innovative learning methods such as PBL in engineering education may be regarded as "the higher engineering education's response strategy to requirements from society". From an engineering perspective, the interdisciplinary perspective that PBL proposes plays an important role since most innovation and real-life problem solving is based on cross disciplinary, interdisciplinary and collaborative knowledge.

The objective of the eCity project is to design a PBL-based educational platform, based on an open-source city-building simulator/game (SimCity like) and explore its simulation engine to support city development problems that relate to math, science and engineering concepts. This platform will be used for two different purposes: to motivate secondary students to an engineering academic path and to scaffold learning for higher education engineering students. This will happen simultaneously as students from both education levels will form heterogeneous groups where the older students can guide the younger ones in the finding of the correct solution.

The development and expansion of the (virtual) city will be accomplished through the involvement of the platform users, with the availability of problems and challenges with different levels of complexity. The challenges and problems listed in the (virtual) city are based on real life situations and the learners' solutions exploited in the resolution or improvement of those situations can then be based on their experience from the real

world. For example, students must design an energy efficient school campus or develop plans for a sewage system. Therefore the virtual city can be considered as a graphical representation of the infinite number of problems that arise every day, in real-life, giving the learners a closer touch with their future professional responsibilities. Furthermore, they will be able to address problems collaboratively, working with colleagues from other European countries, namely Portugal, Spain, Italy, Greece and Turkey.

2 A Virtual City Environment to Foster Interest in Engineering

The eCity virtual environment [4], available on the eCity portal [5] is designed as a PBL-oriented, online, collaborative VLE platform, based on a city-development simulation engine that stimulates the integration and continuous exploitation of Problem Based Learning. The platform will be used collaboratively by students from secondary and vocational schools and higher education engineering schools.

ECity's PBL VLE is expected to be a general and stimulating context especially due to the nature and complexity of the range of problems that will be available in the virtual city. The platform will also promote a sense of belonging to a community, peer support and an additional rewarding system that includes reputation points for problem solving allowing the establishment of rankings (promoting an healthy competition); the "immortality" of the learner's work – his/her contribution stays registered and can be accessed by all the users from the game beginnings, stimulating once more the recognition motivation mechanism (Fig. 1).

Fig. 1. The eCity portal

Also important is the fact that the platform will be integrated in a clear pedagogical methodology, PBL-oriented, to ensure that the upmost relevance is given to the learning process, not the technology. Problems or challenges can be fed into the platform as homework, teamwork, curricular activities, extra-curricular competitions, big or small projects, etc. PBL can be incorporated within existing structures with little disruption as it can be implemented in a variety of forms. Therefore it is not necessary to change the curricular organization as problems can be formatted to different time and work schemes (Fig. 2).

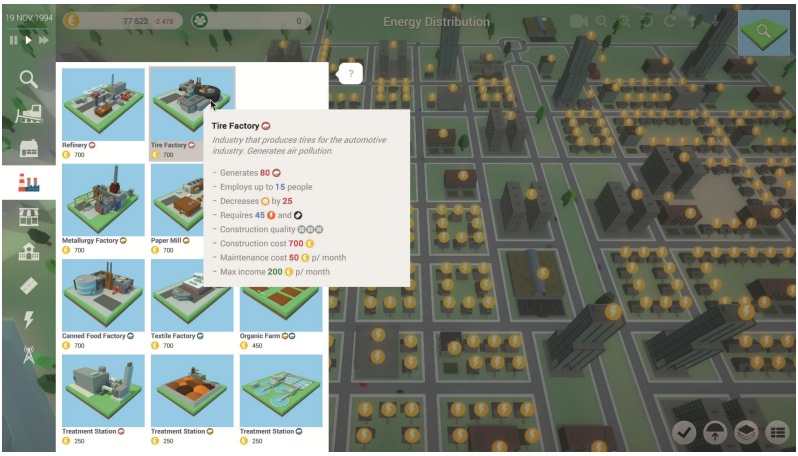

Fig. 2. The eCity virtual learning environment

3 The eCity Project Outcomes

As concrete results, the eCity project will produce several outputs. The first on is an online, collaborative, supporting simulation platform based on the engine of a city-development simulator. This PBL environment is designed to allow an easy transfer of learning from and to other realities due to the enjoyable, dynamic play that replicates real contexts and provides practical training for very specific situations. It is freely available during and after the project for other engineering institutions and secondary schools.

A set of 8 ready-available problems, platform setups and pedagogical guides for free use has also been created. These problems are configurable and customizable, for instance to reflect real situations in the partners cities. They address the following issues:

- Energy Distribution. The objective of this scenario is to learn and understand basic knowledge about energy distribution. There are different types of voltages used for the electrical current, and the one needed for a domestic usage is not the same than the one needed in a factory, which itself might differ from the one produced by a power plant.
- Renewable Energy. This scenario aims to motivate the students in the problem of energy supply in general and to familiarize them with the renewable energies as alternative methods to produce energy.
- Internet Connection Coverage (ISP). The main objective of this scenario is that students know and understand basics of data distribution networks. They could achieve some basic concepts of the ISPs (Internet Service Providers) and data distribution while they are playing.
- Mobile Phone Coverage. This game is introduced as an initial contact with the basics of the design of mobile network (MN), and students will be able to deploy different elements, only antennas to simplify, that make up a mobile network on a map of a given city.

- Earthquake Protection. This scenario focuses on creating a city that is protected against earthquakes and on raising awareness about earthquake protection, itself part of curriculum in countries like Turkey, where serious earthquakes are expected to occur but most of the buildings are not protected against earthquakes.
- Flood Protection. The main objective of this problem is that students know and understand the basic actions to be put in practice in order to prevent and control a flood.
- Pollution. The main objective of this lesson is for the students to know and understand basic notions about pollution and the action needed to prevent or remediate to pollution.
- Bus Network. This scenario has a main objective: make students analyze and design an optimal graph structure, represented by the implementation of a public transportation network.

In addition to those scenarios, all users will also be allowed to play the game in a sandbox mode. In this situation there is no given goal or set deadlines and constraints and the user can play with the virtual city environment in a totally free fashion (Fig. 3).

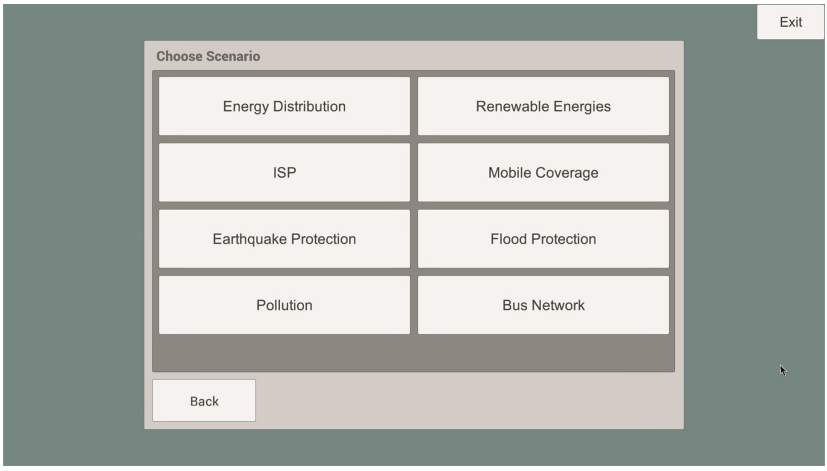

Fig. 3. The 8 engineering problems currently available in the eCity VLE

The project also produces a validated pedagogical methodology to integrate the eCity platform that can be replicated in other engineering schools. In fact this methodology is composed by two different complementary approaches:

- On one side, it will be the engineering students themselves that will develop new challenges and problems. This way they will be directly applying the concepts learned at higher education.
- On the other side, they will be solving the set of project-developed challenges plus the new ones with the support of secondary/vocational students. By doing this they will scaffold their engineering learning but will develop other skills like leadership, group work and collaboration.

Finally, the project shapes a motivational methodology, to be used in secondary and vocational schools to integrate the eCity platform as a complementary activity for students to develop their interest and motivation towards engineering.

4 Conclusions

The eCity PBL-based EVL and the accompanying methodology have been designed with the objective of contributing to help students in the secondary and higher education level with engineering-related courses and issues, and to foster their desire to successfully pursue an Engineering-related career.

The software and all related activities are currently under deployment in real-life contexts in secondary schools and Universities in Greece, Portugal, Spain, Italy and Turkey. In the project scope it will be possible to directly reach about a thousand individuals from the different countries involved, shared between teachers, high school students and university students.

Early results demonstrate so far a positive impact on the engagement of students and high degree of motivation thanks to the engaging and captivating software.

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