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Executive Summary

An engineer requires specific personal, social and professional competencies. Some of these competencies are not being fully developed by the traditional teaching/learning methods. Problem Based Learning (PBL), especially when supported by Virtual Learning Environments (VLE) has been demonstrated to successfully develop those competencies in many cases. This report collects and synthesizes exemplary cases and contextualizes the use of urban simulators as a VLE to support PBL in Engineering in order to allow a precise environment specification for the eCity platform.

The first part of the report is about educational games and the analysis of existing initiatives and solutions related to their educational use. A domain study about educational games focused on the identification of best practices has been carried out to guide the development of the eCity proposals. A summary table with all the reviewed projects and their main features is included.

The second part is focused on the design of PBL environment. This has been approached taking into account both pedagogical and technical point of views. A description of the main principles and ideas underlying PBL is included to sustain the development of the eCity PBL proposal. In addition, we produced a questionnaire administered to eCity partners to identify their requirements and constraints. This part also includes the design of the evaluation methodology that we will carry out in the project to check the benefits provided by the eCity solutions.

Last, it is done a compilation of all the games that project partners have suggested for eCity project so far. The objective of these games is to make more powerful the learning in engineering and similar fields. It should be noted that in actual state of this document games are not totally completed yet, and not all of them will be performed. It will be necessary the collaboration among all partners to set them out.

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1. Introduction

1.1. Reminder of the context

The difficulty that secondary education students have with Mathematics and other Science topics is a widespread problem in Europe as stated by several international comparative studies like PISA or TIMMS. This prevents these students to follow a technical academic path like Engineering. This is not due to lesser skills of these youngsters but mostly due to wrong teaching strategies. We cannot forget that this generation is the "net-generation" or "digital natives": they quickly absorb information in shorter chunks, they expect instant responses and feedback and they want to be active in their learning.

Problem-based learning (PBL) is a learner-centred educational pedagogy in which students develop their ability to go through a problem solving process, usually based on real-life situations. Engineering is one of the areas where PBL is a valid learning alternative and reportedly the benefits for engineering students are considerable improvements in critical, lateral and creative thinking, problem solving skills, group collaboration and communication skills. 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 player to decide, to choose, to define priorities, to solve problems, etc.

The main objective of the eCITY project is to design, develop and validate a pedagogical methodology, supported by an online, collaborative, city-development simulation engine (Simcity[1] like) that stimulates the integration and continuous exploitation of Problem Based Learning in engineering schools but, at the same time, fosters the interest in Engineering in secondary school students.

This report presents the result of work package 3 that handled the specification, design and development of the PBL virtual learning environment and the pedagogical methodology associated with this. Therefore it includes the conceptual aspects but also the technical aspects related to the platform.

1.2. Scope of the task

The WP3 activities along the first months were:

- Analysis of existing best practice in other projects, European and international projects.
- Analysis of existing tools and associated copyright issues.
- Definition of the pedagogical methodology and possible models of use of the eCity platform.
- Design of the PBL environment.
- Design of exemplary problem cases.

[1] Simcity is a multi-player city management game where the player can control a single city or up to 16 cities at once each with different specializations. More information available at: http://www.simcity.com/

- Design of the product evaluation methodology.

WP3 has a close relationship with all eCity work packages but it is meant to provide the basis for work package 4, development of the platform and problems, and work package 5, implementation and test.

1.3. Structure of the document

Besides this introductory chapter, this document is arranged as follows:

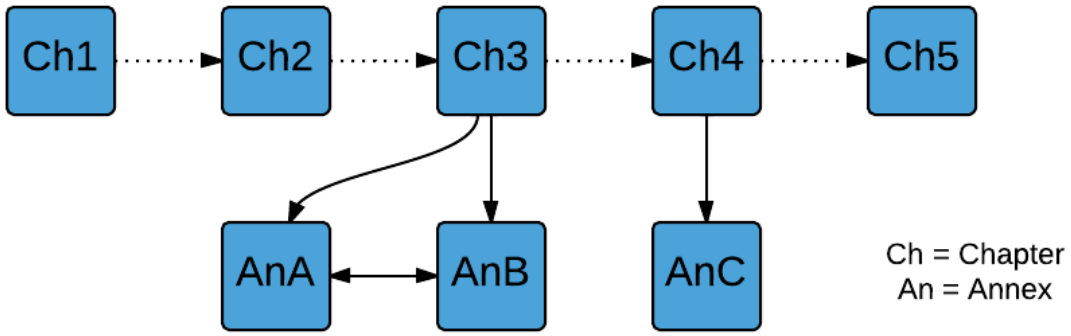
- Chapter 2: The objective of this chapter is to define the pedagogical methodology and the possible use models of the eCity platform.
- Chapter 3: Presents the results of an analysis of related European and international projects, games and tools that can be used to support eCity platform development. The gathered information presents trends that can be used in serious games and in similar projects.
- Chapter 4: This chapter consists in the presentation of potential problems that can be implemented in eCity.
- Chapter 5: Introduces the design of the product's evaluation methodology.

Four annexes complete the document contributing with more information:

- Annex A: Collects all analysed projects and their main characteristics.
- Annex B: Summary table with all analysed projects.
- Annex C: Full description of the potential problems.

Finally, the document includes bibliographical references.

1.4. Structure Map



2. Virtual Learning Environments for Problem Based Learning in Engineering

The Oxford dictionary defines “engineer” as a derivation from the Latin words ingeniare ("to contrive, devise") and ingenium ("cleverness") [1]. Therefore an engineer is a creative practitioner that mixes scientific and technical knowledge with ingenious to develop efficient (effective but with minimum resources) solutions for problems and projects. Engineers link scientific discoveries to their applications to human needs through new technological solutions. They analyse problems, conduct and narrow research, analyse criteria, propose and select solutions and take decisions. Engineers weight different design choices and select the option that best matches the problem requirements [2]. Engineers identify, understand, and interpret the constraints in order to produce an efficient result [2], [3].

In recent years criticism regarding engineering education has grown and it has it been pointed [4], [5], [6] that higher education courses fail in providing engineer graduates with critical skills such as: the ability to work in multi-disciplinary teams; the ability to lead a team; the ability to communicate effectively; the capacity to retain important knowledge and to have a solid mathematical and science reasoning; the ability to adapt to new and different problems; the capability to analyse those problems and to find solutions by using solid problem solving strategies; to be effective long life learners [4], [5], [6], [7]. As previously stated, these are the core skills and competences expected in a professional engineer. Therefore new pedagogical methodologies must be introduced in engineering education to ensure that future graduates have those skills. The sooner future engineers get in contact with real-life problem solving issues, the better [3].

But in fact this issue is not exclusive for Engineering: one of the major objectives of the Bologna Process was to improve the competences and skills of graduates by aiming at student-centred learning [8]. And the Europe 2020 strategy proposes a closer collaboration among all the stakeholders towards the development of sustainable innovation [9].

2.1. Problem Based Learning

Problem-based learning (PBL) is a learner-centred and an application-oriented pedagogical methodology in which students are assessed on their ability to go through a problem solving process, usually based on real-life situations. Engineering is one of the areas where PBL is a valid learning alternative/complement to the traditional learning methods. Some authors [10], [11], [4], [12], [13], [14] 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 skills and collaboration with society and regional development. According to Kolmos, President of the European Society for Engineering Education and Professor at Aalborg University, the implementation of innovative learning methods such as PBL in engineering education may be regarded as “the higher engineering education’s response to requirements from society” [3].

From the engineering point of view, the interdisciplinary perspective that PBL proposes plays an important role since most innovation and real-life problem solving are based on cross disciplinary, interdisciplinary and collaborative knowledge [3], [14].

There are several examples and experiences that use PBL, such as the ones at Maastricht University, Victoria University and Université Catholique de Louvain [4]. A study from the engineering magazine Nyhedsmagasinet Ingeniøren [15] judged and compared competences and skills between graduates from Aalborg University (AAU) and the Technical University of Denmark (DTU). The study showed a significant higher competence by AAU graduates (trained with PBL) in disciplines such as project and people management, contact and working relations, innovative and creative skills, knowledge of business and overall education quality.

It has been suggested [4], [5], [7], [11], [14] that European higher education institutions should consider "shifting to PBL as this learning methodology meets the current needs in engineering education". In these studies it was also acknowledged that there are some implementation/integration problems like the fact that PBL is more time and resource consuming, in order for the learner to approach, analyse and develop a problem solving strategy. According to the same authors, each engineering school and department "needs to decide if PBL is in alignment with their respective teaching and learning philosophies" [5] while taking in account that "PBL can be incorporated in the entire curriculum or at a component level, such as in courses or units of courses" and that "the extent of incorporation of PBL in the curriculum depends on financial and personnel resources as well as time constraints and the readiness of faculty and students". It is then important to notice however that PBL can be incorporated within existing structures without much disruption as it can be implemented in a variety of depth forms [4].

2.2. PBL's phases

Have distinguished the following phases in the development of a PBL activity:

- Preparing students for PBL. The goal is to achieve that students find in PBL an authentic learning experience. For that, is presented really what they can do and are given the first observations.
- Identify the problem. Students receive a brief introduction of the topic that will try and is presented a real situation in which there is a particular problem. After discussion and analysis they should identify and understand the problem. Then they should divide the problem into smaller problems and define the relationships.
- Identify what students know and what they need to know. Students identify the main issues related to the problem and decompose, if they can, into subtopics. Through questions, comments and giving advice, the tutor/trainer tells them what they know and what they need to know.
- Set goals and learning plan. At this stage students should make the learning plan and decide what their goals are. For that they can do:
    - Understand and identify the relationships between the prerequisites. Set up and break down the learning goals and objectives.

  - Establish a set of learning actions coordinated to achieve the objectives. If students work in groups, they may distributed tasks and define which is the task of each one.
- Learning knowledge. It aims at supporting students in data collection, the acquisition of knowledge and understanding of the new information and how it affects in problem's resolution. According to the learning plan, students individually or in groups collect information in books, web sites and any other resources, take notes and can even make recordings. With all that information they meet up with other students to transmit it to them. They may even write reports at the same time that they advance in the process. Throughout this process students can count on the help of the tutor if they deem necessary. He can lead them, guide them, help them, etc.
- Apply knowledge. Students discuss the problem and suggest hypotheses and approximate solutions. They can have to tell to the tutor their oral or written provisional solutions. If there are differences, they can discuss possible solutions and get to a consensus. If the solution is not adequate, they start the process again from the beginning trying to reach the optimal solution.
- Evaluation. In this stage the benefits and consequences of each possible solution are evaluated. This requires to evaluate the generated solutions and their compliance with the conditions of the problem, in addition to evaluate the acquired knowledge. To reach the solution, students must continually make decisions. The correct path in the moment of take decisions will do that they obtain the right solution or not.

2.3. Virtual Learning Environments for PBL

Most PBL courses and activities still rely mainly on traditional face-to-face activities. Nevertheless it has been suggested that Virtual Learning Environments (VLE) enhance the PBL experience and effectiveness [10], [16], [17], [18], [19], [20], [21].

A VLE is an online (frequently Web 2.0 based) education platform that models conventional real-world education by integrating a set of equivalent virtual concepts for contents, lectures, tests, assignments, classes, classrooms and other academic resources [22], [23]. These tools have the potential to increase the communication between a larger number of educational actors [24], [20], [25], [22], [23]. The definition of VLE encompasses a large number of different types of learning platforms:

- A Computer Supported Collaborative Learning (CSCL) system is a groupware application system that enables geographically separated stakeholders to conduct synchronous and asynchronous PBL activities [24]. Such a system manages a collection of shared information objects and communication channels through which users can interact with each other. It usually supports real-time presentation and manipulation of that shared information so that users can see real-time operations induce changes to that information [26], [23].
- In Game-Based Learning, games and simulations are instantiated for learning as they involve mental and physical stimulation and develop practical skills – they force the player to decide, to choose, to define priorities, to solve problems [27]. 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 [27]. These virtual learning environments are specifically designed to change behaviours and impart knowledge and are widely used in training situations [28], [29], [25], [27].

- A wiki is a social tool that allows users to modify, edit or delete its content via a web browser using a simplified mark-up language or a rich-text editor. Wikis are typically created collaboratively by multiple users [30]. Wikis also provide history pages that allow users to monitor the changes made to the content pages. They are relatively easy to deploy and to use and this makes them particularly useful in an educational setting. Students can concentrate on learning and collaborating rather than developing a new technical competency, and teachers can monitor individual contributions to the collaborative effort [30].
- A type of VLE that is rapidly increasing in interest is the Multi-User Virtual Environment (MUVE) or Virtual World [25]. It allows multiple participants to access virtual worlds simultaneously, communicating with teammates via an instant messenger interface, and to interact with digital artefacts, including the users' digital representation, known as avatars. In general, MUVEs enable multiple simultaneous participants to [31], [32]:
    - Access virtual contexts.
    - Interact with digital artefacts.
    - Communicate both with other participants and with computer-based agents, enacting collaborative learning activities of various types.
    - Take part in experiences incorporating modelling and mentoring about problems similar to those in real world contexts.

Second Life is now the most common used MUVE in education (even at a tertiary level) [33], [34], although cases of PBL support in engineering could not be found. Most of MUVEs are currently directed to non-tertiary education, maybe because of the bigger interest in games-like environments on that age by the users [29]. A good example is the River City Project developed at Harvard University (USA) in which the students travel back to the 19th century and by working together in an online environment use their 21st century skills and technology to address existing problems [31].

Other example of a MUVE is SLOODLE - a dynamic learning environment which links Second Life and MOODLE [35]. Through the immersive graphics and the improved interaction capabilities it overcomes existing VLE limitations like the lack of user bonding and the motivation to use it [35], [25], [31]. Although MUVEs can be varied educational environments they are mostly seen as an adjunct to both face-to-face and distance teaching (namely other online applications) [34].

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.

All these environments can greatly aid the integration and exploitation of PBL in engineering education, engaging the learner in activities that simulate the demands of real life professional practice. However it is not easy to effectively implement a distance PBL approach. Some limitations in the design can be appointed:

- The strategies for implementing PBL-VLEs should support teachers in developing and designing locally sustainable solutions to the challenges they face, while respecting and maintaining the teachers' autonomy. Sometimes this is disregarded [23], [34].
- Collaborative VLEs deeply rely on group dynamics as social interaction is a key factor for collaboration [23]. It is not guaranteed that just combining students into groups and giving them all the tools they need, this will lead to effective group collaboration and collaborative learning.
- One main inconvenience of the current learning systems, resides in the low interaction among the different tools, forcing the student to move among different environments, hindering its concentration [36].
- Lack of customization in aspects such as the range of possible problems design, environment, students' and groups' progress tracking [37]. Some VLEs are also too specific and although they were designed essentially and are used with success in some course or subject they could support a wider range of students if a higher level of customization was provided.
- The use of a VLE has to obligatorily motivate the student and the tutor presenting them both clear perceptions and results of improvement by using it.

Within the academic community, a number of web-based, e-learning teaching platforms have been proposed and developed to enhance the PBL experience. The next section presents a variety of existing PBL-VLE platforms worldwide, together with a brief description of the different types of the platforms along and the conclusions based on their use. This supports the conclusions about the level of importance, enhancement and effectiveness of VLE platforms on PBL.

2.4. Best-practice in PBL through VLEs

Some exemplary cases of the use of VLE to support PBL have been put in place. That is the case of the following projects and initiatives.

2.4.1. CROCODILE (CReative Open COoperative DIstributed Learning Environment)

A relevant VLE that supports PBL, mainly due to its theory and concepts (one of the first to introduce the concept of metaphors in VLEs), was developed by Yongwu Miao [26], [24], [38], [39]. According to the author, CROCODILE was one of the first VLE to support scheduled, synchronous PBL activities performed by a small group of adult learners and to emphasize the role of mediation of cultural and social factors to promote those collaborative activities [26]. The developed environment consisted of four components: the virtual institute metaphor, the PBL-net, the PBL-protocol, and the PBL-plan [26].

The virtual institute metaphor reflects parts of the culture used in traditional learning environments enabling the ability of the users to be aware of learning contexts, to interact with learning contexts, and to create and modify their learning environments - it is designed and implemented to organize learning contexts, to support rich forms of social interaction, and to facilitate orientation and tailoring of the virtual learning environment [24]. The actors or users move from one location to another (virtual rooms) to find specific tools, resources and other actors that would help them in the solving process.

PBL-net provides a graphical knowledge representation language, which facilitates the pursuit of mutual understanding and the construction of shared knowledge. Therefore, it serves as a guide during the collaborative problem learning and solving process by enabling students to explore, to negotiate and to reflect about themselves and their shared knowledge [26].

PBL-protocol offers a role-based and state dependent access control mechanism, which can support situated roles. It represents how tutors, learners and experts are expected to behave during the learning process – behaviours restrictions.

PBL-plan enables learning groups to define their own collaborative learning plans in a computational form by defining actions and relations between actions [26].

2.4.2. Smart project, Moulinette and M@roc Téléformation (MTF)

According to the authors (Kamoun N., Bousmah A. et al. from the Doukkali University, Morocco), problem-based learning can be divided in three main phases [40]: pre-project or modelling phase, project or realization phase and post-project or evaluation phase. The objective was to develop collaborative VLEs and tools that could support and provide interactive tracking data and semantic reports in each phase to all the actors, therefore enhancing the effectiveness of the existing PBL sessions.

To enhance the PBL experience and effectiveness, in the first phase two VLEs were developed - Smart-Project and Moulinette – being their objective to support teachers in the modelling and implementation of PBL [17]. Smart-Project is a multi-agent system to support online student group projects where 3 types of actors are defined: technical-teaching team (who defines the projects and problems), student groups (one student is the manager and main spokesman of the group) and tutor (who provides guidance and orientations). The objective of Moulinette is to support content production for PBL sessions, making the task easier and faster through content modelling based on macro design.

The collaborative VLE called “M@roc Téléformation (MTF)” is based on a workspace metaphor which puts in scene locations like in a real university and its objective is to support the second phase – the project or realization phase [17]. Tools that are integrated by MTF allow the consultation of e-learning contents, uploading of required documents, the planning of the learning events by using an additional agenda and the collaboration and communication between users on MTF VLE (learner-learner and learner-tutor collaboration by forum, chat, etc.).

To support the third phase a multi-agent system called "Multi Agent Reporting System (MARS)" was proposed in order to extract relevant data related to the interaction of the various actors and to give semantic statistics and appreciations of the PBL session [17].

Authors concluded that the developed environments played an important role in the structuring and supporting of effective PBL sessions.

2.4.3. PBL Modelling through UML and XML

Pereira and Pinto from the Computer Engineering Dep. of the State University of Feira de Santana (UEFS) developed a PBL VLE whereas the modelling of the PBL method using UML diagrams and its mapping in XML schema based on the PBL tutorial sessions allowed the implementation of an application that supports distance collaborative learning PBL tutorial sessions [41], [19].

Once the tutorial session was opened by the tutor, students were able to access a virtual room with a different level of user permissions through a login box. Students could view general information about the chosen session (such as the group, module, tutorial group, coordinator and secretary), the problem and the student's operations. They viewed it through a "PBL frame" that contained the information registered by the members of the tutorial group such as goals, hypothesis, doubts and evaluation of the tutorial session by the group members. Another important feature was the "tutor's observations" frame that enclosed the orientations and guidance provided for problem solving by the tutor to the students along and between tutorial sessions. The tutor could register problems and orientations on the platform and consult all the information registered on the "PBL frame" facilitating the orientation through all the important steps and goals.

The participants identified some advantages in using this approach: Students that assumed the roles of secretary and coordinator could now effectively participate in the PBL tutorial session due to the saved time in data recording process; Learners who had special needs (e.g. deaf and mute) could effectively participate in group discussions; Tutorial sessions were possible at distance; As most students were from different cities and returned home on the weekend this PBL VLE could allow them to carry out a complete tutorial session at distance. It was noticed an improvement in the learners' motivation through the using of the PBL VLE application. Therefore the authors concluded that in order to support the PBL tutorial sessions, the PBL VLE application was recommended [19].

2.4.4. ProbSolv

The course of ENG1101 Engineering in the University of Southern Queensland uses a wiki named ProbSolv [30], [42]. The fact that 80% of the learners are off-campus students that are taught at distance makes the implementation of virtual teams essential in order to solve the proposed problems. A virtual team is a team whose members share a common purpose or goal, work interdependently and are generally physically isolated from the others [30]. In ENG1101 virtual teams work on specific projects that give them a shared purpose, and members are linked only by communication technologies and tools (the ability to work in a VLE has been recognized as important for future engineering as the technologies involving Web 2.0

are becoming popular) [30], [43]. Wikis can add potential value to the success of a virtual team performance [30], [44], [42].

Approximately two thirds of students have reported that the wiki was a positive influence on their team work, and facilitators (observing their teams) have witnessed increased interaction and collaboration between team members resulting "in improved learning outcomes" [42].

2.4.5. PBL for Electrical and Electronic Measurement

The Faculty of Engineering from the University of Rome "La Sapienza" developed a PBL VLE that allowed the students of the course of Electrical and Electronic Measurements to perform an unlimited number of virtual instruments measurements [4]. An experimental laboratory is a very important component of courses in Electrical and Electronic Measurements and the web based laboratory was a solution found to the limited number of existent measuring workstations, the limited time that the students could use them, the availability of a tutor and the students' need to access the exercises at later times. The requirement of a solid instrumentation hands-on can be satisfied by the possibility to perform virtual measurements at any time by remotely accessing a library of experimental exercises accompanied with theoretical explanations, step by step instructions and other support documents. Another important feature this VLE includes is the possibility of the student to perform self-assessment.

Students must log into the VLE to access a structured ladder of virtual exercises simulated by means of a LabVIEW virtual instrument that would also grant the access to the real exercises on laboratory if the minimum score was reached (otherwise they must work autonomously and repeat the exercises). The fact that the students train freely and as many they want without the fear of failure or damaging the equipment or being judged and evaluated as they perform their experiments gives them a good indicator of their own current theoretical and practical knowledge.

The results showed that the students were more motivated, with more active participation. There was a great improvement on the students' awareness, ability to learn, time management, level of knowledge and effectiveness in the laboratory. Another positive aspect was the fact that laboratory usage dropped about 50% [4].

2.4.6. Controlled Model Elevator

VLEs with access to real time remote experimental equipment have a vital role to play in education. A VLE was developed at the Educational Media Research Centre (EMRC) and ECE Department at the University of Limerick to facilitate collaborative learning in a PBL environment using an interactive and remote controlled model elevator that was made available to electronic engineering students [45], [46].

The VLE was designed so the model elevator could meet the requirements of remote experimental equipment along with the following criteria [46]: Modular design, so the different modular features of the elevator could provide challenging PBL exercises for learners; A web-based system that allowed continuous access from any place; A self-contained open source schematic editor for digital circuit design and modification; Communication between

the schematic editor and the remote experimental equipment; Feedback from the remote experimental equipment (Webcams were installed to view the systems reaction to user input); Open Source technology was incorporated wherever possible to provide re-usability and to minimize project expenditure - Moodle was chosen to be the interface that would assure the interaction between the students, the teacher and the remote equipment presenting itself as the front end of the project [46].

From VLE log files and a post questionnaire it was found that most students used the VLE as a reference tool rather than a learning tool, although from an overall perspective students were satisfied with the VLE. The fact that the VLE and its contents were available at all time and from anywhere was a recognized advantage along with the possibility of keeping track of the learners' progress, grades and login times [45].

2.4.7. IMELS

An interactive and open-shell VLE that incorporates web-based technology and adopts a problem-based learning approach to the teaching and learning of industrial engineering was developed at the Department of Industrial and Manufacturing Systems Engineering at University of Hong Kong [47], [37].

The main features of this VLE include: a flexible configuration and updating of content materials through XML-based configuration files; a multimedia portfolio of industrial engineering; an electronic knowledge base; Virtual Enterprises; a virtual company suit that presents the problem; tools that ease collaborative and group work such as chats and forums and provides support for teachers and subject experts in answering students' queries online and to help them to accomplish their learning objectives.

The objective of the system is to expose students to a learning environment which is seemingly full of complex case problems incorporated in a highly authentic context proving a "real-life professional training". This experience is achieved and enhanced by the design of the virtual company concept where realistic scenarios, staff, dialogues and documentation use a computer-animated form.

Another important feature of IMELS is the open-shell architecture design which allows different configurations, through a client-based interface that runs on users' PCs and a server-based repository, being the virtual companies capable of being dynamically configured to cover and supply any problem the tutor wants to provide. Yet, according to the authors, this flexibility and efficient form of creating and supplying cases of study or problems can be further enhanced to form an information portal for industrial engineering where even "practicing industrialists can make use of such a portal to exchange their experiences whereas academics can use the material as realistic case studies in the teaching and learning of the discipline".

The authors [37], [47] referred that from "the positive feedback from the evaluations undertaken, it was found that the system also facilitates the formation of a collaborative

learning environment thereby creating learning communities in industrial engineering amongst students".

2.4.8. Nucleo

A VLE called Nucleo, developed at the Dept. of Software Engineering and Artificial Intelligence at Complutense University of Madrid, encompasses a PBL framework that is staged in a 3D immersive virtual world (a metaphor) where traditional mechanisms of multiplayer role playing games are followed [48], [25]. Efforts on the framework resulted already in two different applications (Mundo Nucleo and Mare Nostrum) that were integrated under a blended learning form in Spanish higher education [48], [34]. It was intended to be used within the context of a LMS (Learning Management System) - Moodle is being used to support the development of Nucleo learning scenarios in courses by combining built-in tools of the LMS and specific plug-ins.

According to the authors [48], [25] Nucleo employs four main combined strategies to increase the effectiveness of collaborative learning experience:

- The context is a multiplayer role game staged in a virtual fantasy world to enhance students' motivation and to create a favourable atmosphere that lead to the creation of an effective community of practice.
- Formation of heterogeneous collaborative teams.
- Assignation of functional roles.
- Dynamic reconfiguration of teams and members' roles.

Some results from the cases studies were already published by the authors [25], [34]. For instance two different case studies [25] regarding computer programming courses (C++) at university level were analysed where data concerning drop-out levels, approval rates and marks were compared between students who followed Nucleo's approach and the ones who continued with the traditional learning methodology. The statistical data showed with a level of significance of 0.95, that the drop-out levels were highly reduced among the participants in both study cases (65.8% in the traditional approach and 9.1% with Nucleo's on the first case and 72.3% versus 7.04% for the second) while the approval rate of students significantly raised (18,4% with the traditional approach and 59,8% with Nucleo's on the first case and 23,2% versus 56,1% for the second).

2.4.9. Conclusions

Engineers, who were traditionally shaped by experience in real life situations, are presently expected to come ready from engineering higher education schools. Employers now seek graduates that possess great lifelong learning skills, who know how to tackle and solve problems in the real-world, who hold key/transferable skills such as communication, team work, presentation and advanced digital literacy. Therefore the current education system may need to be reformed as the traditional approach might be no longer productive to face the challenge and keep to the change.

In this introductory chapter of this report we presented some existent VLEs used to support and enhance PBL experience and approach. According to what can be found in the literature most of them are based on very specific cases and their objective is to address particular kind of problems. Regarding the cases selected from the literature and respective authors' conclusions VLEs can in fact improve PBL experience and effectiveness. It can be argued that an accurate measurement supporting such conclusions would require wider experimentation as most of the conclusions are based on (small to medium size) surveys, exams results data (the most common) and perceptions. Questions have been raised about the capability of those traditional exams to correctly assess the understanding level of a subject from a student. Opinions are of combining peer and self-assessment, reports, presentations and exams to a more correctly judging of students' abilities and skills. However this referred evaluation apparatus is a much more PBL related as its philosophy and learning approach are student-centred and application-oriented whereas the process of learning includes self and peer assessment, evaluation of the ability to select helpful information to the group, levels of active participation and a higher number of presentations and discussions to perform.

3. Analysis of existing best practices related to the use of games in PBL and engineering education

A search of existing projects related to eCity was conducted to perform an analysis of best practices about the use of games in PBL and engineering education. The main search criterion was the use of games with educational purposes. The analysis of the projects was performed taken into account directions proposed by Squire [49] and Catalano [50]. As a result, a relatively large variety of games was found, from city simulators, e-health games, games to teach programming, games to improve teaching practices, etc. In Appendix A there is a brief description of all the analysed projects. In Appendix B (see chapter 7) there is a short summary of the reviewed projects and their main characteristics.

3.1. Best practices

3.1.1. Academic knowledge needed to play

One possible practice to follow in games is the use of academic knowledge as a tool to achieve goals. This means that to play the user will need to have some previous knowledge and, in addition, such knowledge must be expanded to move forward in the game itself. There is therefore a kind of binomial fun / knowledge. Knowledge becomes a necessity to succeed in the game, which will motivate the learning of it by students.

Usually this binomial relation fun /knowledge is reflected in the availability of various levels in games and the need to gradually acquire to go to the upper levels. For example, in the case of projects like KTS or HIPON [51], [52] (see section 6.2), previous knowledge in a particular branch of medicine is required.

Note that in some cases it is not necessary to have a certain initial knowledge, just enough student's curiosity, and the game itself would be enough to provide or promote such knowledge. For example, in the case of Alice [53] (see section 6.6.6) is the game itself responsible to provide students with the fundamental concepts for computer programming.

3.1.2. Sophisticated design techniques.

The availability of an attractive platform that changes the learning process into an interesting and motivating process can improve learners' engagement and motivation. Therefore, using sophisticated design techniques is another best practice. These techniques allow to provide scenarios as close to reality as possible, with characters and situations in which the players can feel reflected. The graphic qualities should be high and the system must respond quickly to user actions.

If a student feels reflected in avatars or feels that he/she faces on common situations in his/her usual day, it is quite feasible that he/she gets more interested with the game and finds a solution to problems. An example of this may be the simAULA [54] project (see section 6.4.1), which reproduces classroom experiences similar to reality, also providing proximity and comfort. Another good example may is Re-Mission [55] (see section 6.1.2). This serious game, which seeks that young cancer patients can know more about their disease and not feel fear of the unknown, has excellent graphics, that allow to see in detail cell walls, tumours, etc.

3.1.3. Multiple scenarios

Not all students have the same level of knowledge or curiosity and games usually include multiple scenarios focused on different profiles, like for example Climántica [56], CityOne[57] or CHERMUG [58]. In these systems the game can adapt the level of difficulty to the academic level of the students. The choice of scenario can be used to study different concepts and adapt to specific situations. In some cases the players can choose themselves the game scenario. Furthermore, sometimes users are allowed to create their own scenarios, from scratch or by modifying an existing one.

A wide variety of situations and scenarios can be used to maintain high level of commitment. Stages can be used to achieve different learning objectives or multiple scenarios can be used to achieve the same objectives. In this way the game can be reused in different contexts. For example, in the case of Re-Mission [55] there are six sets of scenarios available. All of them, even in the case of different scenarios, are intended to achieve the same goal: to raise awareness of the disease and encourage patients in their struggle. Games should also include variety of scenarios and random elements that prevent repetitiveness and too deterministic flows. So players cannot predict or anticipate the flow of events.

Most analysed games provide multiple scenarios and even the ability to create their own scenarios, as discussed above. An example of customizing models is SimSE (see section 6.7.1) and example of scenario development is eTrees (see section 6.5.1). Other games do not have different scenarios but multiple levels, such as EnerCities [59].

3.1.4. Promotion of interest and creativity in players

Games should produce interest and inspire creativity in learners. If the student is not motivated learning will be more difficult. Games can raise the commitment of students to become active. Furthermore, they can contribute to maintain the interest at a high level during the game sessions and beyond.

It is also important to eliminate the cognitive load to maintain a high level of commitment and care during the different stages of the game. The availability of several navigation modes or the complexity of the learning objectives can be considerable difficulties in players that can be negatively affected in their commitment and motivation. Students need to acquire knowledge increasing the level of complexity gradually. In any case, balance between fun and learning/ difficulty is needed. This means that the game can neither be a simple funny game without any learning, nor only involve difficult concepts without any incentive.

Related to the best practices introduced in previous sections the fact that some games enable students to design their own scenarios also helps to develop their creativity.

As an example, RoboCode users are motivated by the competition, trying that their programmed robot be the best of all [60] (see section 6.6.5).

3.1.5. The promotion of social interaction

Social interaction of players should be promoted. This is an opportunity for students to acquire knowledge and improve skills such as: to relate to others, to discuss and give opinions, to listen and be heard, to speak in front of an audience, to gather information, etc. This is achieved by blogs, forums, wikis, discussions in the classroom, group work, etc.

Real-time communication typically occurs in face-to-face workshops or in web conferences where decisions are made collaboratively. However, these options are not the most used ones. Asynchronous communications through emails, blogs and wikis are more common. These tools minimize the problems associated to the constraints of time and space because the distribution of participants in different countries and time zones.

Most games allow the possibility of playing in groups such as the case of Re-Mission [55]. In EnerCities [59]events and competitions are organized in the community of players to raise motivation. A blog, discussion forums and even a guide for teachers are also available. Other examples, such as CLASHE [61] and Alice [53], have also forums and blogs that facilitate and promote social interaction.

3.1.6. Promoting the use of games

Another practice that should be performed is to promote the games. Games should be promoted to the widest possible number of people and places. Many advantages can be derived from this dissemination effort, including improvements in the platforms themselves because the increased usage and scope demands it. Some mechanisms to promote the use are: speeches, organize events and meetings, and competitions.

Today, with the importance of social networks, it is highly recommended to use them as a tool to promote the game. In fact, this was done by the majority of the analysed projects. Another interesting aspect is that some tools, such as Re-Mission [55], (see section 6.1.2), are available for use in mobile devices and this provide an event greater scope.

3.1.7. Communication on social networks

Currently social networks play an important role. They allow us to transmit information almost immediately and reach even the most inaccessible places that look. Many of the analysed games allow sharing information on social networks and even some of them to play games directly on its system. The most widely used networks are no doubt Facebook and Twitter.

Most of the projects reviewed have some form of communication and / or relationship with social networks such RoboCode [60], simAULA [54] o V-ALERT [62]. There are even cases, like EnerCities [59], (see section 3.2.2) which are available to play directly from them, in this case from Facebook.

3.1.8. Multilingual and multiplatform

The available of a game in multiple languages and in multiple platforms is directly linked to the promotion of its use and to social interaction.

Multilingualism seeks to break the language barrier and the difficulties associated with language, trying to provide the same conditions to all users, whatever language they know. The vast majority of analysed projects are available in several languages. There are very few cases in which they are available in just one language, English, such as in Re-Mission [55] or Gamestar Mechanic [63]. For Torcs [64], although it is available only in English, manuals are available in other languages.

In addition, it is also interesting that the games are available for multiple platforms increasing in this way the opportunities of use. Of the studied projects most are available for Windows, Linux and Mac OS X. Furthermore, it is more frequent to find games available for mobile devices, such as Re-Mission [55].

3.1.9. Games development

Depending on who and where they are intended to be used, the development of games varies. In case of younger students the development effort is usually focused on attraction and simplicity based on collaboration. In the case of university students, the goal is to acquire complex knowledge in a simpler way. Different cases can be distinguished:

- SGSCC [65], (see section 6.6.2), produced a gameplay oriented to people with learning disability.
- CLASHE [61], (see section 6.6.3), allows teachers to adapt the game and the scenarios to professionals, primary or secondary students of primary.

3.1.10. Facilitate learning tasks

Another best practice that can be considered is the facilitation of learning tasks. This may be implemented initially as an informative phase that serves to draw the attention of students and explain the rules and the objectives to be achieved. During the game the tutors/educators can provide help and guidance to the learners. Once the game ended discussions can be organized to consolidate learning, or even the evaluation itself can help.

Many times it is required that certain project stakeholders, such as educators and experts from outside in the project, are involved to provide appropriate information and guidance. A good example is the case of eTrees [66], where it is made available material, assessment tools, scenarios, etc. In CHERMUG [58] students are guided by peers and teachers.

3.1.11. Evaluation

A proper evaluation is key to get a good result in projects. Among other things, evaluation provides information about the most troubled parts. Contrarily, it also allows to identify the most successful parts, which provides guidance to follow the right path in development of the platform. Due to the great importance of this best practice section 5.3 is devoted to this issue.

Some examples are the SGSCC project [65], which gives a high relevance to the evaluation, and HIPON [52], where evaluation involves ICT specialists.

3.2. Games with an urban simulator and educational perspective

Urban simulation is intended to model the development of an urban area, reflecting the most important features that conditions/fosters that development. Urban simulators are used in the most diverse contexts and environments, from professional urban planning and sociological studies to games. In the context of the eCity project urban simulation is used as a game environment that supports the setup and resolution of problems and challenges to be used in the context of PBL. Therefore it was important to analyse existing urban simulation games and platforms for the development of urban simulation to assess their suitability for the project objectives.

As mentioned before, the analysis of urban simulation games was limited to games that were developed or can be used with an educational perspective. This allowed restricting the analysis to a set of games with special characteristics that make them fit for this purpose instead of doing an analysis of an extended range of games.

3.2.1. SimCity and SimCity Edu

SimCity[2] is an open-ended city-building computer and console video game series. In SimCity, the player is given the task of founding and developing a city, while maintaining the happiness of the citizens and keeping a stable budget. The player must define zones, each having limits on the kind of development that can occur there. Development of the zones is not performed directly by the player, but happens when certain conditions are met, such as power supply, adequate transport links or acceptable tax level. The residential zones, in green, provide housing; the commercial zones, in blue, provide shops and offices; and the industrial zones, in yellow, provide factories, laboratories and farms. There are three different densities in the game: low density for small buildings, medium density for low to mid-sized buildings, and high density for anything up to large tower blocks.

SimCity EDU is a special version of SimCity designed to teach STEM (Science, Technology and Mathematics) in classrooms. Educators are able to use SimCity EDU with virtual lesson plans and other games that adhere to U.S. Common Core standards of teaching, which are standards to provide a consistent approach towards effective college and career preparations.

Figure 1. A screen shot from SimCity.

[2] http://www.simcityedu.org/

3.2.2. EnerCities

EnerCities[3] is an educational game about energy, co-funded by the European Commission. The game is about energy sources and the balance between people, planet and profit. The EnerCities game starts with a small village and a small piece of land to build on. A drag-and-drop interface lets players build structures (e.g. residential and industrial areas, renewable / non-renewable energy sources, green zones) to expand the city (see Figure 4). The gamer needs to balance people, planet and profit while supplying the growing city with sufficient electricity, implementing energy conservation and CO2 emission measures and minimizing fossil fuel use. Each player's decision influences the scores for people, planet and profit. When done well, players receive more potential city space to expand their city and to utilize extra available game options. The game allows players to execute several strategies and see the results of their actions on the long term. The duration of the game is approximately 15-45 minutes, depending on the player's strategies.

The EnerCities project [59] aims to provide an e-learning game for young people to experience the implications of the use of energy. In addition to the game, it offers a blog for communication and learning among students, and a guidance document for teachers to develop methodologies for inclusion of the game in the class. The discussion forum EnerCities project is available at the following URL: http://www.enercities.eu/community/. As curiosity and novelty, the game is available on Facebook.

At higher, to inspire and motivate students and schools, 6 regional events, 4 game competitions, 1 community platform and 1 final conference was organized.

As a technical requirement for using EnerCities, which is a 3D game, you need to have installed Unity Web Player (available at http://unity3d.com/). Moreover, it is a fit to play in teams with a low budget.

Figure 2. A screen shot from EnerCities.

[3] http://www.enercities.eu/

3.2.3. ElectroCity

ElectroCity[4] is an online computer game that lets players manage their own virtual towns and cities and also teaches players all about energy, sustainability and environmental management. Players are given complete control over a small town within New Zealand so that they can build stuff, destroy stuff, and even leave stuff alone. The game starts with a natural environment and low population and the town's electricity is generated by one small wind farm Players then need to balance the city's growth with its environmental impact. Citizens need electricity and jobs, but they also love their clean green image. So the player gets to decide whether that forest should be made into a national park or logged and turned into an aluminium smelter.

Figure 3 A screen shot from ElectroCity.

3.2.4. EfficienCity

EfficienCity[5] is a virtual town that proposes to simulate the conditions that allow to have lower greenhouse gas emissions, a more secure energy supply, cheaper electricity and heating bills and a whole new attitude towards energy.

Figure 4 A screen shot from EfficienCity.

[4] http://www.electrocity.co.nz/
[5] http://www.greenpeace.org.uk/efficiencity/

3.2.5. EnergyVille

Energyville[6] is an interactive energy game developed by The Economist Group. The game challenges players to power a virtual city through 2030 and keep the economic, environmental and security impacts low in the choices they make. There is a lot of information to explore in the game and it allows students, teachers or anyone who's interested in learning more about the complexities of energy management and how energy affects cities and the lives of their inhabitants.

Figure 5, A screen shot from EnergyVille.

3.2.6. EcoVille

Ecoville[7] is an interactive game which involves building a sustainable energy community that is constrained by resource, pollution and budget limits. It is possible for individual classes to use this game or to take part in an international competition. The Ecoville competition rewards the class that builds the town that best respects the environment (e.g. reduced energy consumption, maximum use of renewable energies, efficient waste management). The town should emit the least greenhouse gases possible while still offering the services expected of a 21st century city. The contestants should respect the commitment taken by European Union at Kyoto to reduce its greenhouse gas emissions by 8 % by on the period 2008-2012 compared to the 1990's level. The winning class will be the class that best integrates the objectives of sustainable use of resources into its town.

EcoVille seems to have been currently discontinued.

3.2.7. City One

In CityOne[8], an IBM game, users experience some of the complex problems facing cities. They can implement changes and understand the results in terms of how various technology solutions can help revolutionize industries within a municipality.

[6] http://www.energyville.com/
[7] http://www.ecovillelejeu.com/GB/
[8] http://www-01.ibm.com/software/solutions/soa/innov8/cityone/

Figure 6. A screen shot from Cityone.

CityOne also demonstrates the advantages of having a more instrumented, interconnected and intelligent world.

Players can quickly see the improvements that are making are reflected in profitability, customer satisfaction and environmental objectives. After playing can compare your scores with other players in the global leaderboards. Like other serious games CityOne expects users win in imagination, interconnectivity, sensitivity, vision and agility, among others.

In order to play you need to register at the following URL:

https://www14.software.ibm.com/webapp/iwm/web/signup.do?source=swg-cityone

3.2.1. envKids

ENVKIDS[9] aims at raising awareness on environmental sustainability and climate change mitigation activities among elementary school youngsters through age-appropriate on-line educational activities. ENVKIDS does not aim to compete with existing environmental education curricula. Instead, it aims to provide value-adding on-line tools that complement existing practices and promote collaboration among European schools. At the same time the activities promote children's' ICT skills.

Figure 7. A screen shot from envKids.

[9] http://ohmpro.org/envkids/

3.3. Analysis of existing development and support tools

This section provides an analysis of existing tools for the development of digital games. There are many tools available to carry out projects like eCity. In addition, there is a great variety of technologies: JavaScript, HTML5, 3D and 2D, multi-platform, collaborative tools, sound editors, etc. There are also proper tools for graphic design or simulation engines.

Below some projects that are interesting for the case of eCity are analysed. Some of them are serious games networks where collaboration and exchange is facilitated, and where many interesting resources are available. Others involve a similar theme to eCity that can facilitate development.

3.3.1. Serious Games Network: SEGAN

The main objective of SEGAN [67] is to create a community of serious games in which to combine theory, research and practice of different European initiatives in this field. The goal is to facilitate the exchange of ideas and experiences related to serious games. This network is supported by virtual tools and events, increasing the visibility and awareness of the benefits that these games have in learning processes.

The purposes of the project are broad and varied, from the creation of a social online portal to the creation of a European partnership, through the development of a repository with products and projects related to serious games, or developing reference documents. Information and assistance by and for teachers, developers and researchers is included.

The games are available at http://seriousgamesnet.eu/games. In the website there are available several resources: games, articles, items for games, resources and engines for games and more. The most interesting for this section would be the elements for games resources and gaming engines. Due to the large amount of resources available in SEGAN is not very appropriate to list them all. It is better to provide direct access to its website in order to obtain direct information of each one. They are available in http://seriousgamesnet.eu/tools.

3.3.2. Games and Learning Alliance: GALA

GALA [68] is a scientific community that brings together users, researchers, developers and educators. It seeks to promote serious games in education. It aims to organize and coordinate research and disseminate events to communicate lessons learned, best practices and tools. It also seeks to promote innovation and knowledge transfer through dialogue.

GALA has a quality plan to provide a common platform that ensures a consistent approach by partners and facilitates the exchange of information. In addition GALA tries to define a solid framework for project supervision and management.

Figure 8. Logo of Gala.

3.3.3. eAdventure

EAdventure [69] is a research project that seeks to facilitate the integration of educational games and simulations based on games in educational process, especially in Virtual Learning Environments (VLE). It develops 2D educational games with special emphasis on adventure type games. Teachers are facilitated the process of creating games in order to give a truly educational value. Games can be modified easily to adapt them to specific teaching and educational needs.

The project is basically a game editor and a game engine. Games can be creating by means of a graphical editor or by going directly to the source documents using the XML markup language. The game engine is the program responsible for executing previously created games. Both tools are written in Java and distributed in a fully integrated way.

EAdventure is available for Windows, Mac OS X and Linux. There is also a multi-platform version whose only requirement is that the system has Java installed.

The project is free software, can be used, redistributed, integrated into other projects and/or modified under the LGPL (GNU Lesser General Public License License) (see section 3.4.5). EAdventure manuals have the Creative Commons license: Attribution-NonCommercial-NoDerivatives 3.0. Like a curiosity eAdventure appears in the SEGAN repository tools.

The main features include:

- XML notation for describing adventures.
- Customizable interfaces.
- Support for adaptive learning scenarios in real time.
- Games packaged with metadata standards.
- Opensource game engine, written in Java and ability to deploy it as a standalone application.
- The platform includes an evaluation function.

In the latest eAdventure version, version 1.5, new features that provide increased power and enhancements to the tool are added. It includes a new look, improved accessibility especially for people with visual disabilities, increased the available languages, included a new educational tool to facilitate the use and understanding of the SCORM standard, improved user interfaces and process of creating games.

3.3.4. Micropolis

Micropolis[10] is a part of the original version of SimCity. The Micropolis simulation parameters or rules are based on city planning and management, including:

- Human Factors: Residential space and amenities, availability of jobs, and quality of life.
- Economic Factors: Land value, industrial and commercial space, unemployment, internal and external markets, electric power, taxation, and funding for city services.

[10] https://code.google.com/p/micropolis/

- Survival Factors: Strategies for dealing with disasters, crime, and pollution.
- Political Factors: Public opinion, zoning, and keeping residents and businesses satisfied with your city and your performance.

Existing tools provide users with the ability to plan, lay out, zone, build, bulldoze, re-zone, and manage a city.

- Plan: Mapping systems give physical and demographic overviews of the entire city.
- Layout: Design living and working areas, road and transit systems, and recreational areas.
- Zone: Set zoning boundaries for parks, residential, commercial and industrial areas.
- Build: Place roads, rails, airports, seaports, fire and police stations, sports stadiums, and power plants.
- Bulldoze: Clear forests for city growth, build landfill along waterways, clear and re-zone developed areas.
- Manage: Using the mapping and graphing systems, gather up-to-date information on traffic density, population trends, power grid status, pollution, crime, land value, police and fire department efficiency, and cash flow. Set the tax rate and funding levels for city services.

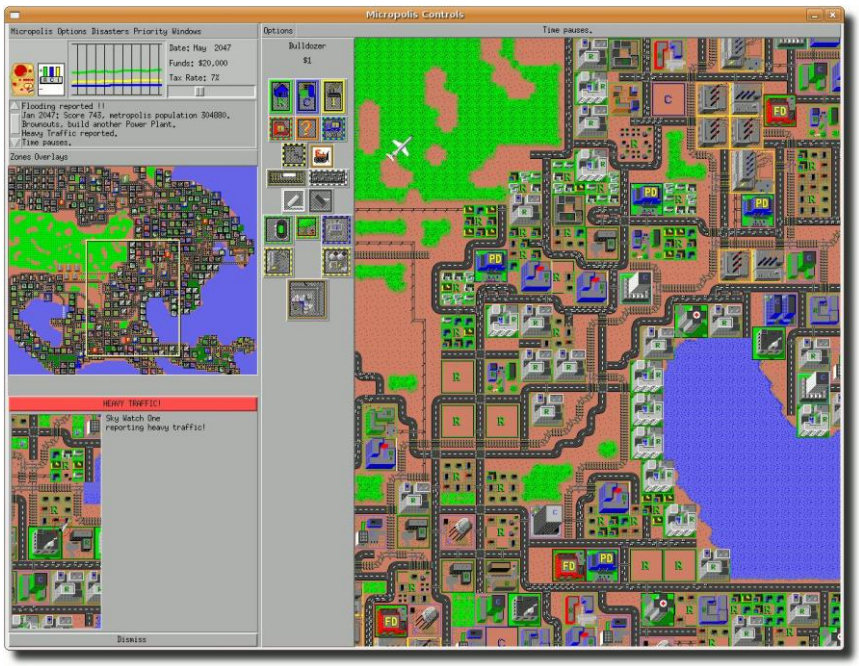


Figure 9. Screenshot of Micropolis.

This is the version of the cities' simulator SimCity, see section 3.2.1, released under free software license GPL 3 [70]. Basically is the created version of SimCity to OLPC, "One Laptop Per Child program."

The Micropolis' core has been rewritten with C++/Python and the code is divided into several modules. In this project it is used the Wingware Python IDE. There exists also an Android

version and a Java version, for example. All available information such as Micropolis source code, wiki and downloadable versions, are available at https://code.google.com/p/micropolis/.

Micropolis presents additional terms under section 7 of the GNU GPL, available at https://code.google.com/p/micropolis/wiki/License.

3.3.5. OpenCity

OpenCity[11] is another 3D city simulator where the user can build residential, commercial and industrial zones, supply them with necessary goods and watch them grow up. Currently the user can build roads, electric lines, electric plant, trees and the three standard RCI zones.

Figure 10. Screenshot of OpenCity.

This is a city-building game under the license GPL [71]. Is available for multiple platforms and allows only play in single player mode. To play it is necessary to download it. In the resources section of the project website can be found UML diagrams, design documents and information on other topics. Programming is done in C + + and using OpenGL and SDL library, the latter under the GNU LGPL license.

3.4. Licensing issues

From the point of view of licenses it is interesting to know Creative Commons (CC) proposals [72], and how they differ from copyright and public domain [73], and the specific software licenses (see Figure 11).

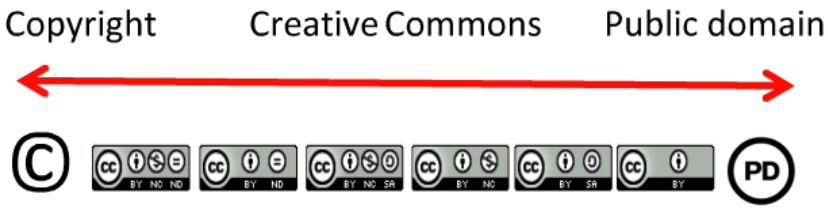


Figure 11. Relation among Copyright, Creative Commons licenses and Public Domain.

Notice that in case of serious games there is a combination between content educational resources/contents and software. In this point appears a dilemma: what is really what you need to license? Which has higher priority? For that reason will discuss CC, that are used to license educational resources, and software oriented licenses.

[11] http://www.opencity.info/

Furthermore, following the preliminary analysis of the projects, it has been observed that most of those who are still developing, especially in their early stages, are not licensed and do not have any reference to any license. In general the few who have licensed use the GNU GPL and GNU LGPL.

3.4.1. Creative Commons

Creative Commons (CC) is a nonprofit initiative that offers free, easy-to-use copyright licenses to specify which rights to reserve and which rights to waive about a piece work. The licenses provide a standardized way to give the public permission to share and use a creative work under conditions of choice from the default "all rights reserved" to "some rights reserved". The CC licenses are not an alternative to copyright. They work alongside copyright to enable a person to modify the copyright terms. Next Table 1 shows the CC licenses in version 4.0. Previous versions have been produced and many resources are available with them. For each license type, a human-readable summary and a legal code is available.

This set of CC licenses is extended on the most restrictive side by the copyright, prohibiting any type of usage for the resources, and on the most permissive side by offering the resource to the public domain

Table 1: Creative Commons licenses v4.

		Can someone use it commercially?	Can someone create new versions of it?
Attribution CC-BY		✓	✓
Attribution-ShareAlike CC BY-SA		✓	✓ but licensed under CC BY-SA
Attribution-NoDerivatives CC BY-ND		✓	✗
Attribution-NonCommercial CC BY-NC		✗	✓ but licensed as NonCommercial
Attribution-NonCommercial-ShareAlike CC BY-NC-SA		✗	✓ but licensed as CC BY-NC-SA
Attribution-NonCommercial-NoDerivs CC-NC-ND		✗	✗

3.4.2. How to License Materials

The goal of European OER Policy Project (OER) is to support the adoption of OER policies in Europe. It aims to promote the best practices and high standards of the CC and OER communities within the educational sphere. This project proposes licensing all educational content (both textbooks and other educational materials, such as educational games) that is being produced in Europe with public funding (both at European level and in member states) under a free license (CC BY or CC BY-SA). There exist some considerations for licensors and licenses that should be taken into account before licensing a resource, such as:

- Irrevocability.
- The type of material. CC is appropriate for all types of content, except software and hardware (in case of software specific licenses are recommended, such as Free Software Foundation or Open Source Initiative, see section 3.4.5).
- If the resource includes rights held by others, make sure to get the permission to sublicense.

3.4.3. How to Attribute Creative Commons Licensed Materials

Accordingly to the previous section all Creative Commons licenses require that if we use a licensed work we need to attribute the creator. This means that we have to acknowledge the creator of the work we are using, as well as to provide any relevant copyright information. There is a guide [75] from the Australian CC section (license CC BY 3.0) that illustrates how to attribute appropriately. The basic principles are:

- Credit the creator.
- Provide the title of the work.
- Provide the URL where the work is hosted.
- Indicate the type of license it is available under and provide a link to the license (so others can find out the license terms).
- Keep intact any copyright notice associated with the work.

3.4.4. Where to search licensed OER

OER are distributed across the Web. There are many services that can be used to find them, but Google is a reference point. A general search with Google returns vast amounts of resources, most of which are not openly licensed for reuse. Instead you can use Google Advanced search. Scroll down in advance search and set “usage rights” parameters to “Free to use, share, or modify”. More specifically, you can find licensed OER in many other services according to their type. For example, related to games:

- Simulation and Animation: PhET (https://phet.colorado.edu/)[76].
- Audio/music: Jamendo, Mixter, Free Music Achieve, SoundCloud.

3.4.5. Specific licenses for software: GPL and LGPL licenses

In the case of software licenses it is interesting to know the proposals of the Free Software Foundation and of the Open Source Initiative that are organizations dedicated to promoting free software and open source, respectively.

Free Software Foundation (FSF) is a foundation that seeks to promote the development and use of free software in all areas of computing. As an example the foundation develops the GNU operating system. As the foundation itself says its mission is "*to preserve, protect and promote the freedom to use, study, copy, modify, and redistribute computer software, and to defend the rights of free software users*" [77], [78].

Open Source Initiative (OSI) is an organization dedicated to the promotion of open source. The organization itself is defined as "global non-profit organization that promotes and supports the open source movement. Among other things, the organization maintain the Open Source Definition and a list of licenses that comply with that definition" [79].

The FSF movement is mainly focused on the moral and ethical aspects of software, and technical excellence is secondary. In the case of OSI movement the priority is get the best code from a technical point of view, sharing source code for get it.

Using the definition that makes the FSF about free software [80], licensed by Creative Commons Attribution-NoDerivs 3.0 United States License (CC BY-ND 3.0 U.S.), it has that a program is free software if the program's users have the four essential freedoms:

- The freedom to run the program as you wish, for any purpose (freedom 0).
- The freedom to study how the program works, and change it so it does your computing as you wish (freedom 1). Access to the source code is a precondition for this.
- The freedom to redistribute copies so you can help your neighbour (freedom 2).
- The freedom to distribute copies of your modified versions to others (freedom 3). By doing this you can give the whole community a chance to benefit from your changes. Access to the source code is a precondition for this.

In the case of open source, like free software, a program must meet certain requirements to be considered open source. These requirements are consistent with the four freedoms of free software. These requirements, following the definition of the organization [81] and under Creative Commons Attribution 4.0 International License (CC BY 4.0), are:

1. Free Redistribution
2. Source Code
3. Derived Works
4. Integrity of The Author's Source Code
5. No Discrimination Against Persons or Groups
6. No Discrimination Against Fields of Endeavour
7. Distribution of License
8. License Must Not Be Specific to a Product

9. License Must Not Restrict Other Software
10. License Must Be Technology-Neutral

Both organizations have in their web pages lists with all available licenses:

- FSF licenses are included at: https://www.gnu.org/licenses/license-list.html.
- OSI licenses are available at: http://opensource.org/licenses.

GPL and LGPL licenses are explained next in more detail because they are used in most of the reviewed projects.

GPL license

GPL, acronym for General Public License [82], is a FSF license that is used in the software world and allows end users to freely use the software in addition to study it, copy it and modify it. The main objective of using this license is to declare that the software is free software. It is a free software license, copyleft and can be used with other licenses.

The full terms of the GPL license can be obtained from https://www.gnu.org/licenses/gpl.html.

Some of its features are:

- Use of the GNU GPL requires that all improved versions that are published are free software.
- The GPL requires that the maker of a version put his name on it, in order to distinguish it from other versions and to protect the reputation of others responsible for maintaining the program.
- The publication of any way to an improved version should made available to users the modified source code, under the GPL.
- The license requires that all copies include an appropriate note on his copyright.
- Every work must include a copy of the license, so that anyone who obtains a copy of the program will know its rights.

LGPL license

LGPL, acronym for Lesser General Public License [83], is a license that is used in the world of software that aims to guarantee the freedom to share and change software, ensuring that the software is free for all users.

This is a copyleft license, compatible with GPL, and can be used along with other licenses. The full terms of the LGPL license can be viewed on https://www.gnu.org/licenses/lgpl.html.

The main difference between the two licenses is that the LGPL license can be linked or used for non-GPL program that may be free or not free software. Also, the LGPL license can convert any LGPL code in GPL code, which facilitates a direct reuse of code LGPL in GPL code, for example.

4. Definition of the pedagogical methodology and possible models of use of the eCity platform

In this chapter a possible use model for PBL in eCity is proposed, following the pattern suggested by Yongwu Miao [84].

4.1. Introduction

The objective of the eCity project is to design a PBL-based educational platform, based on an open-source city-building simulator/game 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. And 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.

This project searches a new, innovative, pedagogical methodology for the learning process in engineering academic organizations that complements a motivational strategy for secondary and vocational school students. The project follows a development methodology based on educational content and application development.

Methodology is composed by two different complementary approaches:

- 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.
- They will be solving the set of problem-developed challenges plus the new ones with the support of secondary/vocational students. By doing this they will scaffold their engineering learning and develop other skills like leadership, group work and collaboration.

Main features of the pedagogical methodology:

- Motivational methodology: in secondary and vocational schools, eCity platform will be a complementary activity for students to develop their interests and motivation towards engineering.
- Multidisciplinary approach (for different engineering areas).
- Combination of secondary and higher education students.
- Problem solving collaborative approach that allows students from different countries to work together in a problem.
- Problems can be configured and customized by teachers for specific issues or even to represent real local situations.
- New problems can be created by other users.
- Includes reputation points for problem solving allowing the establishment of rankings, promoting a healthy competition.

- The “immortality” of the learner’s work as long as it can be accessed by all the users from the game beginnings.
- 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.

4.2. Relevant PBL’s characteristics for eCity

To identify the requirements for the implementation of virtual PBL environment, important features of PBL are analysed according to the stage and literature.

4.2.1. Rich forms of social interaction.

Traditionally the students receive knowledge passively and individually through a series of units that teachers explain. The communication exists primarily from teacher to student and not in the other direction or through cooperation among students. PBL, in contrast, incorporates collaborative teams to solve problems. Thus the interaction between students and the teamwork are promoted, improving in this way interpersonal skills of students.

In PBL the students are the active agents in charge of the whole process of learning. Teachers and others who may be involved act as facilitators in the learning process. New forms of communication and collaboration appear.

4.2.2. Problem's structure.

Usually to solve a problem it will be necessary to merge knowledge from various disciplines. In this learning process, the more the students deepen, the more questions they will have. They must identify what they need to know, what the problem really is about and what information should be collected. They will learn how to build hypotheses and possible solutions. Through collaborative reasoning processes they can identify inconsistent knowledge, discover the missing knowledge and build shared knowledge.

4.2.3. Roles

In traditional learning, roles are stable and the function of each one often does not change even if the situation changes. In PBL the responsibilities of students and teachers change if the situation changes.

Students' roles in PBL:

- Seekers and problem solvers: students anticipate, explore, analyse and solve problems. They can investigate the causes from multiple perspectives and propose hypothesis and solutions.
- Planners and producers: students can plan and design methods and strategies to resolve issues or problems which result is an original process or product.
- Initiators: students initiate, coordinate and facilitate the realization of collective tasks, anticipating obstacles and obtaining the support of others to achieve results.

- Executants and actors: students apply their skills, information, ideas, tools and technologies to achieve to complete an individual or group task.
- Communicators and negotiators: students can express their ideas, information, feelings, concerns and so on to others clearly so that they can understand and accept them. Students work collaboratively to fulfil the tasks and objectives.
- Explorers and partners: they explore the physical world, materials, technology, to collect the information they need. Also they interact with others and contribute their efforts to the collaborative work.

4.2.4. Teachers' roles in PBL

In PBL the teacher changes the main role to be a simple facilitator of information. The possible teachers' roles are [83]:

- Facilitator: provides rich environments, experiences and activities for learning in an innovative way, using authentic tasks, knowledge and shared responsibility, etc.
- Guide: in a collaborative class, the teacher is responsible for mediating and modelling. He/She also helps the students indicating solving strategies, relating new information acquired with the prior knowledge, etc.
- Co-Learner and Co-Investigator: the teachers, along with the students, participate in the research process with professionals. Thus, with the help of technology, they can switch roles and students can become teachers of teachers.

4.2.5. Self-directed learning

The students are the ones who take charge of their learning. They define learning goals and know what problems are meaningful to them. They break down their ultimate goal into secondary objectives that are reached them gradually. Students may, individually or in teams, share all or part of the information and knowledge acquired. They are responsible for building shared knowledge.

4.3. Possible use model

eCity aims at being integrated into a clear pedagogical methodology, PBL oriented, to ensure that maximum relevance is given to the learning process, and not the technology. This pedagogical methodology includes a full and complex process. It starts with the teacher in the early work stages and ends with the students fully engaged, self-evaluating and interacting.

The following sections provide in detail, step by step, a proposed methodology.

4.3.1. Who will use it?

The eCity platform can be used by students or teachers. Depending on whether the user is the teacher or the student, the way to use it will change.

In the teacher's case, eCity will be used as a supporting tool during the classes. Previously, before teaching the subject, the teacher should organize the subjects and classes, and see how he/she can integrate eCity in the classroom. The teacher probably have to make use of the

facilities provided by eCity for creating new problems or to adapt existing ones, in such a way that with the problems can be used to achieve the desired goals and fit them into a particular theme. Once the teacher has organized the subjects, eCity problems and the time when using them, he/she simply has to pull it off. The teacher will use the platform to mentor and guide students in the pursuit of knowledge with more easily and effectiveness than using the traditional method.

In the students' case, students can use eCity because a teacher request it or by choice. If the teacher proposed the game the student might have to play alone or in groups, in the classroom or at home itself. In case he/she decides play, it will be his/her decision the how, when, where wants to play. We also distinguish the type of student, whether it is a student from secondary, vocational schools or higher education engineering schools. The larger will be the educational level, the more difficult will be the problems and it will be needed a greater involvement and commitment for achieve the solution.

4.3.2. Where will it be used?

According to what was explained in the previous section the possible places of use are basically two: the classroom and elsewhere outside the classroom.

Outside the classroom, the teacher:

- Prepares and organizes classes and subjects.
- Look for problems that are best suited, for this purpose he/she may have to create new problems or modify an existing one.
- Analyses the results and reacts to them, reinforcing a concept for example.

In the classroom, the teacher:

- Presents and teaches the subject, and introduces eCity.
- Indicates briefly how students have to use the platform and solves a small test problem (when students have never used the tool before).
- Indicates how and when students can use eCity.
- Solves doubts.
- Makes search patterns.
- Guide during the acquiring information's process.
- Help to relate new concepts with those already known.
- Participates in the evaluation process.

In the classroom, the student:

- Receives and processes information provided by the teacher.
- Has a first contact with eCity (only if it is the first time he/she use it).
- If the teacher decides, the student begins to use the platform and to solve the problem, alone or in groups.
- Asks the teacher and can be oriented and/or directed in case he/she need it.

- Interacts with peers.
- Self-evaluates and evaluates other students.

Outside the classroom, the student:

- Tries to solve the problem.
- Searches information.
- If he/she uses eCity without anybody, can experiment and mark his/her objectives.

4.3.3. How will it be used?

In this section the most important thing is to define how the students will use the platform. In the case of teachers it is quite clear with the previous two sections, they can do it alone or collaborating with other teachers.

For students, they may work individually or in groups:

- Individually. From home or directly from the classroom, the student has to face lonely to problem resolution. He/She needs to make the whole process only with the help of the teacher, which will be available to guide and orient. The student must identify what is the real problem, break it down into smaller problems and try to go looking for solutions gradually. The student should also seek information and learn to relate this new information with what he/she already knows.
- In groups. The choice of group work usually begins in the classroom, where the teacher divides the class into teams to work with eCity. Teams should be between 5 and 7 members to have a meaningful use. Within each group, students identify the problem, divide the work, pose possible scenarios and solutions in its earliest stages and seek information. Then they meet up again to gather all the information, debate and reach consensus. If they fail to reach the solution, they would repeat the process. Additionally, during the process of finding the solution or at the end of the problem, they can share what they learned and how they have done with other classmates, thus increasing the interaction.

Within the groups each student will have a role to determine its involvement in solving the problem:

- Leader: he/she is responsible for leading the group, making decisions where is necessary and end discussions when he/she sees it appropriate. The leader must ensure compliance with work and foster an atmosphere of collaboration. He/She develops an overall project plan.
- Devil's Advocate: member of the group that has to question all reviews and suggestions. He/She facilitates the debate.
- Secretary: person responsible for reporting the results of the team. Besides he/she files, documents and organizes all the information that the group has.

- Other group members: take individual notes, search for information, trying to successfully make their assigned activity, participate in discussions, and work by and for the team.

Sometimes there may be a member tutor/mentor, that is a student in advanced courses that does similar functions to the teacher but being closer to the students. Even sometimes could act as leader, although is more interesting that this role is occupied by another group member. In the case of the devil's advocate, secretary, and tutor/mentor only can exist a member with that role, but it is not required that it exists.

Usually the students themselves are who assign roles in such a way that everyone does the job best known and where he/she feels more comfortable. At other times it is the professor who does, seeking that all students perform all roles, not only the easier and better roles that they know.

4.3.4. How will it be evaluated?

The evaluation may be made by the teacher or the students, or by a combination of the two.

The teacher can make an overall evaluation taking into account the outcomes of the game, how good they are, how long the students needed to reach the solution, etc. He/She can also consider the working with other colleagues, collaboration, support, the existence of leadership's attitudes, or even how many times he/she has had to intervene. Furthermore the teacher can also make a written, oral or test directly with eCity, to evaluate knowledge acquired by the student.

If the student takes the evaluation it can be a self-evaluation, a comprehensive evaluation of the system or even he/she evaluates their peers. With the self-evaluation the objective is to get the student to be self-critical and to think about what he/she did well and what he/she has done wrong. In the case of the overall evaluation of the system a general student perception of eCity is searched. The peer evaluation is a subjective assessment where often it is more important the competition, or cronyism, that acting fairly.

4.4. eCity Problems Summary Table

During the development of the Specification work package (WP3) that started in the Porto meeting, partners proposed and refined a set of problems to be fitted into the simulation engine. Not all these problems are suitable for integration in the engine but nevertheless the have been included, as they can later be used to support PBL in different forms.

Title	Summary
Road Signs	The traffic signs in our city are truly lacking. Due to a sudden raise in the public infrastructure budget, the city hall has decided to improve the city by starting everything from the ground up and redesigning the signs network. You are tasked with designing a new network of traffic signs all around the city, in order to optimize the traffic and preserve public safety. You'll be provided with a map of the current traffic signs and a count of how many signs the city hall currently has in stock.
Traffic lights management	The traffic lights in our city are truly lacking. Many citizens are complaining about the many traffic jams our city experiences. The city hall has decided to tackle the situation by redefining all the timing for all the traffic lights downtown. You are tasked with designing the new timings and determine how the traffic lights will now work, on a per hour basis. You'll be provided with a map of the current traffic lights and their behaviour and also with a simulation of the typical car traffic per day in our city.
Protection against earthquakes	The area of the city will be near a fault zone. The player will select the correct place by evaluating various factors like the expected earthquake gratitude, history of earthquakes in the area, soil types and combinations, nearness to the fault zone and decide on the type of construction, materials to be used for construction, maybe even the type of concrete to be used, cost of construction, number of floors for buildings etc. There may be archaeological, natural resources and other factors affecting costs and results. For example building the city on a strong ground may be cheaper but it can be far to natural resources. On the other hand building the city near water resources and a fertile land will be financially beneficial but the player will have to construct stronger buildings and that will be more expensive. The player can also plan earthquake awareness-rising activities for the people in the city, which will reduce the number of dead or injured people in a possible earthquake. During the play there will be an earthquake simulation at an unexpected time and results will be seen. The aim is to provide the correct balance between an economic and social development of a city and the life guarantee of its inhabitants. This problem may be beneficial for civil engineering departments and also it will be very useful to make secondary school students, especially living at places near fault

	zones like Turkey, conscious about earthquakes.
Cloud Infrastructure for WhatsApp Servers	Facebook wants to extend the WhatsApp functionalities in our city. The company wants to improve their functionalities trying to provide a good response-time taking into account the number of present and future clients and also the increase in service needs. They need to decide how many servers to deploy, where these servers (memory, computing) are going to be located, the links and capacity among the servers, the energy sources, the needs for redundant systems, backup issues, wifi connections, wireless communications, antennas' distribution, etc. The students could use a game/simulation application to deploy the different elements on a map. The application should show the evolution of the solution in time, taking into account the behaviour of the system when the population increases, in case of some system breakdowns, natural disasters, etc.
Buses to the University and Beyond	The problem involves the need to provide bus services to attend university students, and other collective: K-12, high school students and public in general. Each one of these users has different timetables and travels. The objective of the problem is to optimize the use of buses, supporting all people with the minimum number of buses. We want to reduce the carbon footprint, the number of buses and drivers. Nevertheless, if not enough buses are provided, the people will use their own cars and the pollution will increase. The game/simulation application will show a particular city with some schools and roads. Students need to decide the routes, the number of buses, the timetables, etc. The application will calculate the number of cars needed, the pollution produced, etc.
Emergency service of public cleaning city roads in case of snow storm.	In case of severe snow storm, to establish: a) The selection of the most convenient product to prevent freezing of the pavement. b) The distribution of the cleaning materials in the city to minimize transport and optimize rapid action. The options of anti-freezing materials can be: a) Sand; b) Water; c) Salt ; d) anti freezing liquids. Option b) can be excluded, as in case of low temperature water would produce a crystalline and dangerous ice layer. The choice of option a) rather than c) can be based on environmental reasons. The same applies to option d).
High levels of pollution in the city surrounds farms.	How to select/use the fertilizer that provides a better balance between investment, effectiveness and sustainability? Management of the underground water deposits? The result is not immediate.

Dimensioning energy furniture	Dimensioning an energy furniture for a house, a school, a factory or a shopping center are all important matters for a electric engineer or for a electric technician. When someone decides to build a building he needs to know how many watt he needs to provide the correct energy to the buildings. This problem wants helping students to developing the knowledge and the competences useful to approach and solve the basic and complex electric cases here following: 1. A domestic house 2. A factory that produce small wood objects 3. A school with 1500 students and 60 classes 4. A shopping center with 50 shops 5. Students have to indicate how many Watt these buildings need to absolve their function.

Purification of a natural gas field	The city needs a supply of energy from different sources. The recent prospections in the area have found a natural gas deposit that might provide enough energy to cover up to 20% of the city regular consumption. The analysis reflects a measurable content of sulphur-containing compounds mainly SH2, OCS, CS2, and also CO2, that makes the gas unsuitable in the present conditions. Gas purification involves the removal of the impurities from the gas streams. The primary operation of gas purification processes generally falls into one of the following categories: 1. Absorption into a liquid. a) Basic solution b) Organic solvents 2. Adsorption on a solid 3. Permeation through a membrane 4. Chemical conversion to another compound The student will have to study the content of the impurities in the gas and the highest limit of each contaminant that is allowed in the delivered gas. S/he will have to search the process or processes that can bring the level of contaminants to the needed values. Part II. Optional and for higher education How to distribute gas to the whole city. This task will include the design of the pipeline and pump selection. The student can choose the pipeline material and diameter, in order to obtain the energetic requirements of gas pumping and choose the more appropriate pump. It could be included the calculations of investment and operation of pipeline and pump.

<table>
<tr>
<td>Wind Farm Location (Optimization) Problem – Random Choice? Your Loss</td>
<td>
This is a good example of how important optimization problems are in real life. The understanding of optimization problem solving techniques like linear programming is a key aspect of an engineer oriented student.
On the following example the optimal solution for total cost minimization of installation is €525k while randomly choosing A+B+C+D results on a spent budget of €767k!
Example: Due to E.U. regulations and environmental and sustainability concerns the city has to start producing energy from renewable sources. This implies in this phase the installation of at least 10 MW on wind farms. The maximum allocated budget is €780k.
Wind probabilities studies as economical ones shown the following suitable places for installing the wind farms.
<table>
<tr><td>Place</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td>G</td><td>H</td><td>I</td></tr>
<tr><td>Suitable Capacity (MW)</td><td>2.2</td><td>4.4</td><td>1.1</td><td>5.2</td><td>1.5</td><td>1.5</td><td>2.2</td><td>4.8</td><td>1.0</td></tr>
<tr><td>Cost (k€)</td><td>100</td><td>244</td><td>22</td><td>401</td><td>88</td><td>84</td><td>101</td><td>302</td><td>52</td></tr>
</table>
Due to environmental and city planning issues A and B are mutually exclusive choices
Which of the places should the city choose in order to minimize the total cost of installation? (Other possible questions: Which of the places should the city choose in order to maximize the total installed capacity? Which of the places should the city choose in order to minimize the total number of wind farms?)
</td>
</tr>
<tr>
<td>Code-Living City</td>
<td>The game presents a future city as a living entity that is able to control some of its public services. Particularly, streets are journeyed by automatic buses, taxis and other vehicles that are driven by automatic systems. Students will be required to program these systems, so the vehicles move around the city according to their planned routes to serve the city inhabitants. Students must model the behaviour of these active elements by using programming sentences. This will bring them the opportunity to experiment with programming elements. For example, students will model the behaviour of a bus journeying its route; or will create algorithms to make taxis to offer their services to the inhabitants of the city, etc.</td>
</tr>
<tr>
<td>MyMVNO's Access Network deployment</td>
<td>MyMVNO is a Mobile Virtual Network Operator company that has experienced a large increase of customers in recent years. Being a virtual operator, the company lacks any access infrastructure. In other words, the company does not have its own Access Network (AN) and it has to pay to other providers for using their infrastructure. Therefore, MYMVNO intends to deploy its own infrastructure and it wants to perform some simulations. The objective of the simulations is to verify that the company can deploy its own infrastructure while maintaining service quality (i.e. increasing operator’s revenue) and reduce their operation costs.</td>
</tr>
</table>

Fertilizers	In the farmland that surrounds a city fertilizers are going to be used in a conscious way, careful with the environment. In this sense good care of the ratio of raw materials to add and mix has to be taken into account, fulfilling both legal and environmental requirements and economic aspects. A score will be assigned based on the proximity of the proposed solution to the best one that satisfies the given "restraints".
Formulation of a Clinker	The Portland cement clinkers are mainly obtained by calcination at temperatures between 1350-1450 °C of mixtures of limestone and clays. It is a granular, hard and grey material. In its composition fall silicates, aluminates and ferrites of anhydrous calcium. Clinker is the main component of Portland cements. The raw materials used in the preparation of clinker are of two types: i) Limestone rocks with high content of $CaCO_3$ that by thermal decomposition originate the basic oxide CaO and ii) Clays, sandstone and iron oxides by thermal decomposition generate acidic oxides, SiO_2, Al_2O_3 and Fe_2O_3. Starting from certain raw materials the main constituents of clinker are formed: Calcium silicates $SiO_2.3CaO$ and $SiO_2.2CaO$, calcium aluminate $Al_2O_3.3CaO$, calcium ferrite $Fe_2O_3.2CaO$ and calcium aluminoferrite $Fe_2O_3.Al_2O_3.4CaO$.
Operation of industrial activities.	The community needs to have an industrial base to generate jobs and provide needed consumer goods. This includes installations of various types of industries, such as bakery, slaughter of animals, paint factory, winery, manufacture of ceramic products, vegetable processing plants, dairies, etc. The student will propose the most suitable method to reduce the residues generated by the industry, so that they meet the environmental requirements of the community. Otherwise there may be an administrative penalty or even a temporary closure of the industry. In the treatment of the industrial waste that will be generated, the regulations will be different if the industry is installed in an industrial area, with services provided by the community, or in a non-urban area. In the last case these regulations will be stricter.

Building, setting up and testing a Local Area Network	Actually only software with fee or electronic calculator are available for students that want to improve their theoretical and professional skills in the networks building and setting up. The fundamental proposal's goal is the development of a serious game which allow students to acquire skills and competencies in the informatics sector to be applied in the real world. By playing real-life situations students have to build a Local Network Area (LAN), set it up and test it using specific knowledge inside a simulated and protected work environment. Thank to this proposal the game will consent students to select at least 5 problems where different type e dimension of net, subnet and device have to functioning in a Local Network Area. Furthermore students will have the opportunity to set up new problems by themselves and then try to solve them.
Create a network of food banks for social assistance to the population	The community welfare offices confirm that, at the present time, 3% of the population is in poverty. The aim is to create food banks to periodically distribute batches of food to the needy. The project has to establish the needs to cover 50% of a balanced diet, based on a list of basic food, rice, vegetables, milk, water, etc. For the population of children bellow one year specific food will be provided based on milk and etc. To simplify the problem, the daily calorie intake and the carbohydrate/protein ratio in the supplied batch will be fixed. Known population of the city and the storage capacity of the standard storages, the project can address the calculation of the number of required deposits and the distribution, location and details of food distribution. Distributed food can come from private donations or government subsidies. The entrance to the food bank supplies may vary over time. A different summer and winter diets can be established. The project can be combined with the creation of urban gardens in which low-income citizens can grow some of their fresh foods, fruits and vegetables, legumes. Might involve setting the size of the lots and the type of crop in each season. This second version would be suitable for an orientation of agricultural engineering and will require more technical knowledge.
Network coverage across the city using antennas, cables, hubs	
Energy distribution within the city neighbourhoods	

5. Design of the PBL environment

In this chapter the design of the PBL environment is introduced from a technical point of view. The first section includes the main implementation requirements that should be taken into account. These requirements, as well as the stages and characteristics presented in the previous section, follow the scheme proposed by Yongwu Miao [84]. Then, the general conditions to consider are introduced.

5.1. Main implementation requirements

In order to support social interaction the eCity platform must implement a learning environment as close as possible to a real environment. The Virtual Learning Environment (VLE) should allow each users to know where it is, where to go, where to get the necessary information, what tools can be used, etc. The VLE should enable users to customize it to perform different types of tasks. It should also facilitate interaction and cooperation between users.

The VLE should allow users to represent different types of information and intentions. It would be advisable that could guide the students to take the right path in finding the right solution. It should facilitate the tasks to undecided people, should help to manage the acquired knowledge, should facilitate reasoning, etc.

The VLE must explicitly define the roles and responsibilities that users can have during the learning process. The main objective is to guide and control the behaviour of teachers and students. It should allow users to define their own learning strategies and even to allow them to change them as the problem itself changes.

The VLE must provide a self-directed learning for users. This should allow users to define actions and the relationships between them, should allow the allocation of resources and should guide the user through the process.

5.2. General issues

The analysis of existing similar tools made in sections 3.2 and 3.3 provides information about the tools that could be used in the PBL environment's implementation from a technical point of view. For the full design of PBL environment it is also necessary to consider other issues, some of them already introduced in section 3.1 as best practices.

5.2.1. Graphic design aspects and simulation engine:

Regarding the graphic design, the PBL environment must present an attractive and realistic aesthetic. When users access to the system they have to find a graphical environment as close as possible to reality, that presents incentives that makes attractive. It must respond quickly to user actions and should facilitate interaction.

In the field of graphic design and video games, there are many available tools. For example, according to [85]:

- Graphics engine: its basic functionality is provide a rendering engine for 2D and 3D graphics, physics engine or collision detector, sounds, encrypting, animation, artificial intelligence, networking, streaming, memory management and graph scene. Some examples of graphics engines are SourceEngine, Rage, Unreal Engine3 or Ogre3D. Ogre3D is open source but only a graphics engine. However, it works with other libraries to create an engine with all the desired characteristics. It is possible to add sound library, networking, input, collisions, etc.
- Physics engine: simulates real situations like gravity environment, the clash between characters, etc. Possible libraries are Ogre Bullet or PyOgreOde.
- Sound: facilitates a perfect integration of music and audio. For example OgreAL.
- Graphical user interface: it can be used for example CEGUI, that is a free library that allows the creation of windows and widgets for engines where this functionality is not available natively. (Until version 0.4.1 is under LGPL license. Henceforth, since version 0.5, under MIT license which is less restrictive.)
- Design of scenarios and characters: the Blender program, that allows the creation of 3D models under GPL license, could be used.

5.3. Design of the product evaluation methodology

This chapter presents an appropriate methodology for the eCity project evaluation. The reasons that make necessary an evaluation are explained and possible evaluation patterns too. Evaluation methodologies in similar European projects are analysed and finally an evaluation methodology for this project is proposed.

5.3.1. Evaluation, main features

Why is evaluation necessary? The main reason is that it is the most important tool to improve a product. The evaluation makes it possible to detect and correct weaknesses and to detect the pros that can be enhanced.

When a project is being evaluated, a basic and simple guide that provides the information sought can be followed. A possible guide could be:

- Elaborate a list with evaluation criteria linked to project's objectives.
- Regular monitoring according to the work plan.
- Make self-evaluations of work done.
- Evaluate the generated and collected documents during the project. Assessing aspects such as coherence, relevance, management, etc.
- Use peer evaluation where a group of students is evaluated by other students using a criteria sheet that is provided and made public.

- The evaluation plan identifies the essential elements of the project and the impact that they have on project's success.

It is important to do an internal and an external evaluation, because the internal evaluation may be conditioned by excessive contact with the project and the knowledge of it.

An important aspect is the used tools. It is important to combine quantitative and qualitative methodologies. Quantitative aspects show a general overview and the qualitative aspects serve to go in depth in the causes of success and failure.

5.3.2. Analysis of existing projects

It has done a small review with evaluation methods used in other European projects. Taking into account the results of such a review, we have produced an evaluation method for eCity, discussed in the next section.

SGSCC project

In the case of SGSCC project, there are available online two questionnaires, one of them for the stakeholders and the other one for the beneficiaries:

- Stakeholders: http://games4competence.eu/stakeholders-questionnaire/
- Beneficiaries: http://games4competence.eu/beneficiaries-questionnaire/

Both questionnaires seek to know the opinions of involved stakeholders and beneficiaries of educational computer games. The questions are divided into several groups depending on their subject. There are, for example, questions that seek socio-demographic data, questions related to educational games and others that aim to find out the computer skills that the users have.

CHERMUG project

In this case we can consider in our analysis the variation of practical study cases of CHERMUG project. Depending on the subjects and studies, previous levels of knowledge, where executions take place, the educational purpose or the number of players, among others, one or other results are obtained.

SimAULA project

The simAULA project uses an evaluation methodology that approximates what eCity searches and we will use it as a guide for the design of the methodology of this project.

SimSE project

The evaluation process in Simse project was carried out by four studies that have provided information about its operation and how to improve it. The four studies were:

- Pilot study where 28 students played with SimSE for a few hours and in the end they completed a survey about their experience.

- Assignment an extra credit in an introductory course in software engineering at UC Irvine where students had to play Simse and answer correctly some questions.
- Comparative study using pre and post test in students who played SimSE, students who have used textbooks and students who have gone to conferences.
- Observational study of students that play with SimSE in an environment one by one and later interview about their experience.

5.3.3. Evaluation methodology

ECity, like many other projects and initiatives, basically aims to improve the educational process. It intended that users acquire knowledge, skills and attitudes in a fun, engaging and motivating way. However it may happen that the main objective is not achieved, which is the mere learning, and the whole process will be only a game. To control this possible deviation and to ensure an adequate end for eCity, has a special role the evaluation process. With the evaluation we can know if the student has learned or not, if the platform is right or need improvement, and even if tutors have performed their duties properly.

In the case of eCity project we will use the same methodology used in the simAULA project [54] but adapted to our case.

The complete methodology, with the tools and when and who applies it, is summarized below.

Table 2: Evaluation methodology

WHAT / Indicators	HOW	WHEN	WHO	WHOM
Students data General data Experience with ICT Experience with Virtual worlds Digital literacy Interest for technologies in education Expectancies with eCity	Questionnaire	Previously to the test	Experts Tutors	Users
Overall usefulness Efficiency (time) Global evaluation Learning outcomes ReGame	Questionnaire Interview	Pretest Final assessment	Experts (staff)	Users

Time consuming Satisfaction				
Technology Graphic design No mistakes Close to reality Multimedia: enough, quality, etc. Realism of media Networks, speed Access, rooms Transparency	Questionnaire Interview Observation Computer data	Continuous Final assessment	Experts	Users
Pedagogical aspects Useful to learn User support Close to reality As a complement (sense) Practical Representative / realistic situations Structure and objectives of the game Promotes metacognition Feedback Repetition Value of tutors/machine assessment	Questionnaire Interview Focus Group Computer data	Final assessment	Experts	Users Tutors
Usability No mistakes Learning curve Support given by the app	Questionnaire Observation	Pretest Continuous	Experts	Users

How fast actions can be executed Clarity Similarities with other apps	Computer data	Final assessment		
Engagement (games) Level of focusement Involvement with the experience Realism Usefulness Practical Regame Learning curve	Questionnaire Observation	Continuous	Experts	Users
Sense of presence Naturality Compelling Involvement with the experience Level of focusement	Questionnaire	Continuous	Experts	Users
Learning Adequacy of scenarios Adequacy of contents and objectives Self assessment	Questionnaire Interview Focus group	Continuous Final assessment	Experts	Users Tutors

COLUMNS:

- WHAT / INDICATORS: Premises, aspects to be evaluated.
- HOW: Evaluation technique.

- WHEN: Stage in the process where the tool will be applied.
- WHO: Evaluator that will apply the evaluation tool.
- WHOM: The 'object' that will be evaluated (mainly students)

On the WHAT/INDICATORS column there are six categories of data: students, public services in general, technology, pedagogical aspects, usability and learning outcomes.

To evaluate these indicators, tools of HOW column are used. The WHEN column is used to specify the moment when you have to apply the evaluation tool. The WHO column specifies the evaluator. And WHOM column refers to the goal that has been applied the evaluation.

Categories for indicators

- Students data. It will gather information about the users just before the test. This data is very important because, once compared with the rest of obtained data after the test In this way, it will allow analyse better the achieved impact.
- Overall usefulness. As a global category, we will measure it through efficiency, learning outcomes and global satisfaction of the users.
- Technology. Proposes indicators related to the technical aspects.
- Pedagogy. Introduces the pedagogical elements and go in depth on how the pedagogical strategy behind eCity makes the application successful or not.
- Usability. Gives information about how is designed the game and about if use's facilitations are right.
- Engagement. Focuses on the elements that make eCity an engaging platform.
- Learning. This category is aimed to identify if eCity is useful to learn. The indicators of this category are partly also integrated in the category 'pedagogy', but this group wants to make a difference between the pedagogical aspects and the learning as a measurable and evaluable product.

Methods and techniques of evaluation

There is a mixture between quantitative and qualitative methods:

- Initial assessment questionnaire. It is mainly used to gather data from students. A questionnaire will be delivered via email through Google Forms, which facilitates data working. It would be nice, before providing the questionnaire, explain the project and the evaluation process and try to involve students.
- Interviews. Questionnaires look to get an overview of the results but interviews seek to obtain a more specific vision. There will be a sort of guide for interviewers but there is not a strict direction to follow neither a template of questions to ask. The course and direction of the interview are decided during the course of it.
- Questionnaires. In addition to the initial questionnaire, which collected data about students before their first contact with eCity, questionnaires will be performed a posteriori. Google Forms will also be used and the responses mainly used Likert scales, where 1 means "I disagree" and 5 to "strongly agree".

- Focus Group. This technique, also qualitative, basically seeks interaction among students. Thus, through interaction and feedback, you can get different results than those obtained with the interviews. It also provides facilities to the students to feel freer to participate and contribute. The Focus Group would be occur after the interviews to confirm or deny the results. Once the interviews have done and the results have analysed would be made a guide for these Focus Groups.

When do the assessments?

- Initial assessment questionnaire. Before to use eCity. The questionnaire will be provided by personal of eCity.
- Interviews. After the students use eCity. Only a 10% will be evaluated and the evaluation will be done by evaluators, that have to follow a guide.
- Questionnaires. After to use eCity, the students will receive a questionnaire, given it by evaluators.
- Focus Group. After the students use eCity and some days later that interviews have been done, Focus Group will be done.

6. Annex A: Projects focused on educational games

6.1. General

6.1.1. Playmancer

Playmancer [86] is a collaborative project that brings together 8 partners from 6 different countries and addresses the game to supplement the therapy of mental diseases. It was born with the intention of promoting the use of new technologies in different treatments seeking mental benefits that certify software as an complementary therapy.

Playmancer results, due to the modular architecture of nature and the commitment to follow the Design-for-All philosophy, can be generalized to other serious games applications and user communities.

6.1.2. Re-Mission and Re-Mission 2

This serious game pursuits that young cancer patients are aware of their disease and its treatment [55]. The developers claim that this can contribute to improve the main treatments.

Realtime Associates, Inc has developed these games. It is possible to play as a single player or multiplayer. Re-Mission 2 is also available for Android and iOS devices.

6.1.3. Climántica

This project seeks to raise awareness among young people about the importance of tackling climate change [56]. The project started in 2006 and has four teams: teaching, graphic editing, multimedia and scientific advice. It's basically a simulator of cities, in the style of SimCity, but in this case the aim is the construction of an ecological population. It is primarily aimed at secondary materials and modules of biology and geology departments, but it may also be of interest to history and geography, physics and chemistry, technology and economics. It is aimed at primary school but in a more playful and closer to the childhood fantasy framework. It is available in three languages: Galician, Spanish and English.

In the web site http://climantica.org/ all information and documentation is available. It is possible to play directly Climántica online just accessing to the following link: http://xogo.climantica.org/?locale=gl.

The game is included within the CLIMATLANTIC project, which aims at developing strategies at regional and local level to reduce the carbon footprint in the European Atlantic Area. The project website is http://www.climatlanticproject.eu/eng/index.php.

6.1.4. Gamestar Mechanic

Gamestar Mechanic [63] aims to help elementary students in learning to design games. It has three fully integrated components:

- Play. Through an adventure game users learn the principles of design. As they progress and learn, they gain 'sprites' that will help them to design and publish their own games.
- Design. When players get 'sprites', they can access a design workshop where they can create their own original games. The technique for creating those games is drag and drop. Once designed players can post the games for others to play and review.
- Share. There is a community where players can post, review and collaborate on games designed by other players, providing feedback. Also challenges and contests are available.

There is a user guide for parents, a section for teachers (documentation, blog, etc.).

6.1.5. Torcs

The Open Racing Car Simulator (TORCS) [64] is a multiplatform racing simulator. It is suitable for players interested in racing games, researchers, engineers and teachers. It has available a variety of tracks and cars, and a sophisticated physical model. It supports different input devices, such as steering wheels, joysticks, etc.

At http://torcs.sourceforge.net/ and http://sourceforge.net/projects/torcs/ there is information related to the project files, wiki, etc.

6.2. Medicine

6.2.1. e-Learning serious game for surgical skills training: Kheiron Training System (KTS)

Its main objective is to design, develop and validate a serious game aimed at medical students and young surgeons to support training their psychomotor skills in minimally invasive surgery (MIS) [51].

This game is based on existing training tasks (see Figure 12). With the KTS project medical students are expected to have an earlier surgical training. Similarly, novice surgeons can be trained and specialized without moving to specialized centres. It also aims at enabling students to get access expert knowledge and tutoring.

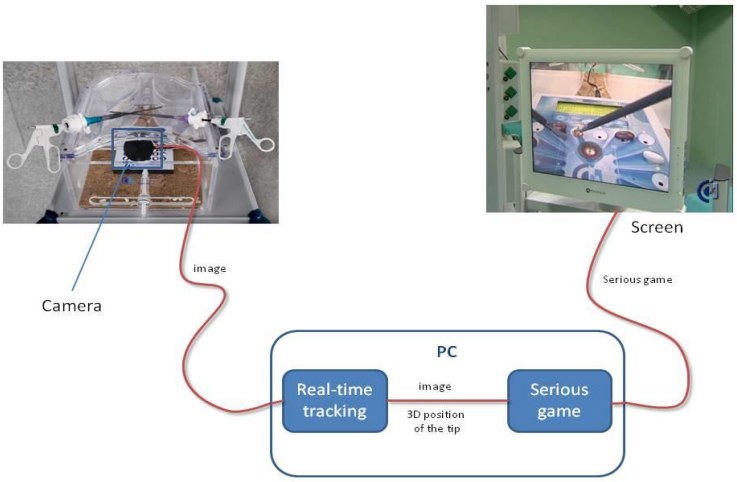


Figure 12. An outline of the operation of the KTS serious game.

6.2.2. E-modules on HistoPathology: a valuable online tool for students, researchers and professionals. HIPON

Project aimed at medical students, pathologists and occupational training that seeks to teach the proper way to treat the tissue samples and recognition of injury patterns [52]. It is intended to convey learning through a web platform and taking advantage of technology advances in the image. The ultimate goal is that end users think like a professional pathologist and gain experience in the relationship of pathological data with other clinical information.

The main components of HIPON project are:

- Virtual Portfolio with update study cases.
- e-Modules on histopathology.
- Online game.
- Histo-book will be the tool for social intercommunication of all parties and act as workspace.

6.3. Information security

6.3.1. Virtual World for Awareness and Learning on Information Security: V-ALERT

V-ALERT [62] is focused on developing a culture of information security. The main objective is to provide a deep understanding of security threats and protective measures and actions.

To achieve the objective of the project a learning environment virtual world, 3D Virtual World Learning Environment, is used. This environment provides:

- Scenarios that present real life cases with information security risks.

- "Safe" exposure to security risks that must be overcome through appropriate actions.

It uses a fully customizable environment, multilingual, where learning can be easily adapted to other scenarios with other threats. It also includes a recommendation system.

The cases of security threats are based on policies and procedures related to information security based on the Standard ISO / IEC 27001 "Information Technology, information security management system." Apart from that standard methodologies and guidelines for security awareness NIST, ISACA, ISC2 and ENISA12 will be used.

6.4. Teaching and Learning

6.4.1. Tomorrow's Teachers Training: simAULA

The goal of simAULA [54] is to provide an online environment where teachers can perform and get practical experience without attending to the classroom. Thus existing and future teachers interact with avatars, to organize and develop lessons and materials taught in virtual classrooms, see Figure 13. Thanks to simAULA teachers and students learn how to improve.

The project aims to collect the most representative country situations, especially the most controversial and problematic. It provides a set of prototype scenarios, but it is possible to create new scenarios.

Figure 13. A screen shot of simAULA.

6.5. Communication skills

6.5.1. An online service to improve communication skills in the workplace using branching stories games: eTrees

The goal of eTrees [66] is to improve the communication skills. Students are faced with real situations in a safe environment. Thanks to this type of training students, in addition to reading and writing skills, acquire skills such as listening, negotiating, conflict resolution and teamwork.

[12] ISO/IEC 27001: http://www.iso.org/iso/home/standards/management-standards/iso27001.htm . NIST, National Institute of Standards and Technology: http://www.nist.gov/. ISACA: https://www.isaca.org/. ISC2: https://www.isc2.org/. ENISA, European Union Agency of Network and Information Security: http://www.enisa.europa.eu/.

It includes a learning methodology based on the game. An online service is available to both prospective students and potential trainers who want to develop their own scenarios.

6.6. Lifelong learning

6.6.1. Exploring and promoting the contribution of ICT and digital media to the development of learning to learn competencies in lifelong learning transitions: eLene2learn

The eLene2learn project [87] seeks basically learning to learn. It is a network composed of multiple universities aimed at supporting the process of learning to learn during transitions that place during the different learning processes. Students' motivation and confidence are promoted in order to develop learning skills.

Includes 60 case studies with methodologies related to the implementation of ICT in the classroom. The workshops and seminars that have been recorded and interviews with teachers and students who took part in the activities are available.

6.6.2. Serious Games for Social & Creativity Competencies: SGSCC

The goal of the SGSCC project [65] is the development of educational games for teenagers/young people with learning disabilities in order to increase their employability. In this case, it plays a very important role the assessments by beneficiaries and trainers, as they are the basis of future development process.

Students face a number of problems and are asked to investigate how social skills can help to achieve significant solutions that are fed directly from the game. A 3D game environment is used where the user in realistic scenarios controls characters.

6.6.3. Continuous Learning Anywhere within a collaborative, knowledge SHaring and Enjoyable context: CLASHE

The CLASHE project [61] aims to incorporate learning gamification features. This involves the use of gamification techniques and dynamics of games and entertainment, particularly [88], [89]: reward, recognition, cooperative play and competition. It seeks to increase user engagement and ensure that learning is a process of continuous collaboration. It involves the use of videos, video, music, simulations, games, blogs, forums, wikis, etc. It is aimed at professionals and students of secondary and university education, which also will be responsible for the evaluation.

6.6.4. Continuing/Higher Education in Research Methods Using Games: CHERMUG

The main aim of CHERMUG [58] is the development of a game that helps students to understand and develop research methods and statistics. It is a series of mini games to support

students understanding the research process. Available games cover both qualitative and quantitative approaches.

In addition to the games themselves, the project has developed six scenarios of use cases, three newsletters and six case studies of best practice guides. They are intended primarily for students in nursing and social sciences. However, since its content is about diet and is of general interest, it be used in other fields. Generally students acquire mathematical skills, digital skills and learn how to learn.

To play any of the games available in multiple languages, you must access http://playgen.com/chermug/.

6.6.5. RoboCode

The main goal of RoboCode [60] is that users learn to program in Java and enjoy it. The game mechanics is basically to program a robot to compete with other robots in the battlefield. The player must program the robot telling him how to behave and how to react to events that occur on the battlefield. The battles are running in real time on the screen. In addition to learning Java programming it is also useful for learning Scala, an artificial intelligence (AI) language.

It is an open source project and is provided under the EPL (Eclipse Public License) terms. Reference links:

- RoboCode web site: http://robocode.sourceforge.net/
- Source code of RoboCode: https://github.com/robo-code/robocode and http://sourceforge.net/projects/robocode/files/.
- Eclipse Public License: http://www.eclipse.org/org/documents/epl-v10.php.

6.6.6. Alice

Alice [53] main objective is to teach students computer programming in a 3D environment. It allows users to create animations using an environment based on drag and drop. This is a free and open language programming, object-oriented integrated development environment (IDE).

Detailed information about Alice, publications, help guides, forums, blog, tutorials, and even the program licenses are available http://www.alice.org/index.php.

6.7. Process models, project management

6.7.1. SimSE

SimSE [90] is an educational simulation environment of software engineering. It is an interactive game that aims to teach students the processes of software engineering in a different way, aside from the large amount of theoretical concepts and putting them directly into practice with realistic virtual experiences.

SimSE is a game for one player that takes the role of project manager for a team of developers. Tasks are, among others, hire and fire employees, assign tasks and monitor their progress. It has a fully graphical user interface where the learner will receive information and take actions accordingly. At higher there are an explanatory tool that provides the player with more information about the game. The player can return to any previous point in the game, running multiple parallel branches and generate new branches while continuing the original game.

The project SimSE allows customization of the software process models that are simulated. They can vary, for example, depending on the type of organization and culture or ideology own instructor. There is a tool for modelling processes that allows instructors to build the model they wish to simulate.

Simulation models of software processes are created using a pattern generator which allows the specification of employees, tools, customers, etc. A generator interprets the model created and automatically generates the necessary code and GUI. There are six models currently available for download.

All game information, materials, models, manuals, videos and even the code itself (open source) are available at http://www.ics.uci.edu/~emilyo/SimSE/.

7. Annex B: Projects Summary

Table 3: Relation of projects features based on the best practices

Project	Year	Field	URL	Multi-platform	Multi-language	Different scenarios	Communication in social networks	Licenses	Main characteristics
SimCity	1989	City Simulator	http://www.simcity.com/	Yes (Personal computer versions, console versions, portable and online versions and online/offline modes)	Yes	Yes (It is also possible to develop customi-zed scena-rios.)	Yes		Blog. Single player and multiplayer. It is not free.
SimCity Edu		Educational City.	http://www.simcityedu.org/	Yes	No	Yes (six different missions)	Yes		Consistent internet connection to play. Special material for teachers. Guides and community online.
EnerCities	2009	eLearning about Energy	http://www.enercities.eu/	Yes (Online and Facebook)	Yes (12)	No, only different levels	Yes (Facebook and Linkedin)		Game + blog+ document guide for teachers + discussion forum. Events and competitions to

Project	Year	Field	URL	Multi-platform	Multi-language	Different scenarios	Communication in social networks	Licenses	Main characteristics
									generate motivation. Technical requirement: Unity Web Player installed.
ElectroCity		eLearning about energy and ecology.	http://www.electrocity.co.nz/	Yes	No	Yes	No		Teacher's registration. There will also be a version to play without an internet connection (Windows and Mac OS X). Guides online.
EfficienCity		eLearning about energy and ecology.	http://www.greenpeace.org.uk/efficiencity/	Online	No	Yes	Yes (Facebook)		Greenpeace game.
EnergyVille		eLearning about energy and ecology.	http://www.energyville.com/	Online	No	Yes (Levels)	Yes		Group game mode. Teachers, students or anyone who's interested. Guided play.
EcoVille	2008	eLearning about energy and ecology.	http://www.ecovillelejeu.com/GB/	Online	Yes		No		Information for teachers and citizens.

Project	Year	Field	URL	Multi-platform	Multi-language	Different scenarios	Communication in social networks	Licenses	Main characteristics
CityOne	2010	eLearning about energy and ecology.	http://www-01.ibm.com/software/solutions/soa/innov8/cityone/		No	Yes	Yes (Facebook and Twitter)		Registration is necessary. Development by IBM.
envKids	2009	eLearning	http://ohmpro.org/envkids/	Yes (online and offline version)	Yes	Yes	No		Online tools to to complement existing practices. Learner resources. Teacher resources.
SEGAN	2011		http://seriousgamesnet.eu/		Yes (9)	Yes	Yes (Facebook and Twitter)		
GALA	2010		http://www.galanoe.eu/				Yes (Facebook and Twitter)		Have a customized quality plan.
eAdventure	2006	Education and Learning in General	http://e-adventure.e-ucm.es/	Yes (Windows, Mac OS X, Linux and multi-platform)	Yes (2)	Yes		Free Software licensed by LGPL. Manuals with Creative Commons license: Attribution-NonCommercial-NoDerivatives 3.0.	Editor + games engine. XML. Java. Evaluation function.
Micropolis	2008	City	https://code.google.com/p/mic	Yes	No	Yes		GNU GPL 3 +	SimCity version created for

Project	Year	Field	URL	Multi-platform	Multi-language	Different scenarios	Communication in social networks	Licenses	Main characteristics
		Simulator.	ropolis/.					additional terms included in https://code.google.com/p/micropolis/wiki/License	OLPC. C++/Phyton Coded divided in various modules.
OpenCity	2003	City Simulator.	http://www.opencity.info/	Yes	No (only info in other languages)	Yes	Yes	GNU GPL	Only one player. Necessary a previous download.
Playmancer	2007	Medicine and mental health.	http://www.playmancer.eu/						Modular architecture. Design-for-All
Re-Mission	2006	Medicine, health, cancer.	http://www.re-mission.net/	Yes (Online and mobile app. Windows Android and IOS)	No	Yes	Lets share content on Facebook. Twitter and Google Plus.	Copyright HopeLab, Inc.	Single player or multi-player modes. Distributed in CD-ROM or DVD.
Climántica	2006	eLearning about energy and ecology.	http://climantica.org/		Yes (3)	Yes	No		4 work teams. Included in CLIMATLANTIC project.

Project	Year	Field	URL	Multi-platform	Multi-language	Different scenarios	Communication in social networks	Licenses	Main characteristics
Gamestar Mechanic	2010	Video Games Design.	https://gamestarmechanic.com/		No	Yes	Yes. Own online community too.		Elementary students. 3 fully integrated components: Play, Design, Share. Use guide for parents. Own section for teachers. Help section Exclusive package for teachers, with specific content. (It is not free.)
Torcs	1997	Car Simulator.	http://torcs.sourceforge.net/	Yes (Linux, FreeBSD, OpenSolaris, Mac Os X and Windows)	No (only manuals in other languages)	Yes. Variety of tracks and vehicles. Content easy to create, add and modify.	Yes (Facebook, Twitter, Google Plus)	GNU GPL	Written in C++. Intended for simple interested users, researchers, engineers, teachers.
KTS	2013	Medicine	http://www.kts-project.eu/		Yes (6)	Yes	Yes, in multiple social networks	Copyright Fundación Centro de Cirugía de	

Project	Year	Field	URL	Multi-platform	Multi-language	Different scenarios	Communication in social networks	Licenses	Main characteristics
							and webs.	Mínima Invasión Jesús Usón	
HIPON	2012	Medicine	http://www.hiponproject.eu/		Yes (5)	Yes		Copyright 2014, The HIPON Project	Evaluation with TIC specialists, students, teachers, academics and professionals.
V-ALERT	2013	Information Security	http://v-alert.eu/		Yes (5)	Yes	Yes (Facebook, Twitter and Linkedin)	Utilisation of the open source concept to all outcomes and structures.	Environment totally customized with a recommendation system. Cases of threats based on standards.
simAULA	2010	Teaching Learning	http://www.simaulaproject.eu/		Yes (4)	Yes	Yes (It is possible to share content in multiple places.)		Multiples scenarios with limited situations but with possibility to create and charge new scenarios.
eTrees	2012	Communication skills	http://www.etrees.eu/		Yes (4)	Yes (It is possible to develop customized scenarios.)	Yes (in multiple places)		Available additional material, evaluation tools, etc.
elene2learn	2011	Lifelong	http://www.ele		Yes (4)	Yes	Yes	Attribution-	Workshops, seminaries,

Project	Year	Field	URL	Multi-platform	Multi-language	Different scenarios	Communication in social networks	Licenses	Main characteristics
		Learning	ne2learn.eu/			(More than 60 practical cases.		NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0)	interviews, etc.
SGSCC	2012	Learning for young and university students	http://games4competence.eu/	Yes (web and mobile games)	Yes (7)	Yes	Yes (Facebook and Twitter)	Copyright SGSCC	High importance to the evaluation through interviews, questionnaires, expert reviews forms, observational checklist.
CLASHE	2012	Learning for young and university students	http://clashe.exus.co.uk/		Yes (4)	Yes (3)	Yes (Facebook)		Gamification. Using music, video, blogs, wikis, forums, simulations, etc. Evaluation: feedback to improve efficiency and effectiveness.
CHERMUG	2011	Learning for young and university students	http://www.chermug.eu/	Yes (directly from the web browser or through a SCORM version)	Yes (7)	Yes (6)			Pedagogical guides from students and teachers. 3 evaluation phases.
RoboCode	2000	Programming	http://robocode.sourceforge.net/	Yes (cross-platform)	No		Yes (Facebook and Twitter)	Open Source licensed with EPL license.	Battles in real time.

Project	Year	Field	URL	Multi-platform	Multi-language	Different scenarios	Communication in social networks	Licenses	Main characteristics
									Complete development environment. Valid to any system with Java preinstalled. Technical requirement: JVM. Last version May 2014.
Alice	1999	Programming	http://www.alice.org/index.php	Yes (Windows, Mac OS X and Linux.)	No	Yes	Yes (Facebook)	BSD license.	Drag and Drop. Forums, blog, tutorials, help guides, textbooks, etc. Programmed in Java.
SimSE	2005	Process models. Project management.	http://www.ics.uci.edu/~emilyo/SimSE/index.html	Yes	No	Yes (6). Customized models too.	No (Only a Google group)	Open Source Code.	Only a player: project manager role. Fully graphical user interface. Additional explanatory tool. Model and simulation written in Java. Evaluation in 4 phases.

Project	Year	Field	URL	Multi-platform	Multi-language	Different scenarios	Communication in social networks	Licenses	Main characteristics
									Available manuals, videos, code, etc.

8. Annex C: Problem definition

8.1. Cloud Infrastructure for Whatsapp Servers

Title
Title of the problem Cloud Infrastructure for Whatsapp Servers
Summary (10 lines)
Give a brief description of the context, goals and expected results of the problem Facebook wants to extend the whatsapp functionalities in our city. The company wants to improve their functionalities trying to provide a good response-time taking into account the number of present and future clients and also the increase in service needs. They need to decide how many servers to deploy, where these servers (memory, computing) are going to be located, the links and capacity among the servers, the energy sources, the needs for redundant systems, backup issues, wifi connections, wireless communications, antennas' distribution, etc. The students could use a game/simulation application to deploy the different elements on a map. The application should show the evolution of the solution in time, taking into account the behaviour of the system when the population increases, in case of some system breakdowns, natural disasters, etc.
Learning Objectives
What knowledge, competences and skills will students develop? To know the size of each type of message (text, audio, video, image, etc.). To know how these messages can be stored in the server (RAM, secondary and tertiary storage). To know the power requirements of the servers, and consequently the power requirements of each message. To know that the servers have to be redundant in order to guarantee the service (What happens if a server crash?) To know the bandwidth of the links among the different servers. To know the antennas necessary to provide the service.
Discipline
Which engineering field (be as specific as possible) is it addressed? *Telecommunications, Computer Science, Energy*
The Task
Define exactly what is the problem that students will have to solve The students have to define the number of users, and according to this number and the number of messages that a user can send what is the dimension of the several servers providing the service. The students have to define the maximum size of a message, the number of messages stored in the server, the maximum time these messages can be stored. All these parameters define

the size and the number of servers and their memory capacity.
To establish the power requirements of the servers, how much they consume and their cost (both, money and ecological terms).
It is possible to connect with other problems, such the generation of (renewable) energy.
To simulate several crashes (server, connection, energy, etc.) and how to resolve them.
To make the coverage map of the several antennas in order to give the appropriate service.

Background

What previous knowledge is required?
Physics, Mathematics

Learning Activity Organization

What resources will be required? How is the learning activity organized?

Resources: computers to play the game/simulation

A classroom with 25 students could be organized in 5 different groups, each group working in a different country (Portugal, Spain, Italy, Greece, Turkey). All the students will receive a common introduction to the problem. In case of high-school students a university student could be involved in each group, acting as a tutor.

Each group works on his country and at the end of the experience they show their results, decisions and design to the rest of the classroom in a presentation.

Gameplay description

What should the students do to solve the problem?

Each country has different problems and issues. The students need to provide a solution and then to run the game/simulation to check how such a solution behaves on time.

The design involves the identification of servers and networks, their distribution around the country and the calculations associated with the properties involved: bandwidth, level of service provided, etc.

Author / Organization

Claudia Azevedo, Manuel Caeiro, Andrea Bianchi, Lucio Faré and Martin Llamas.

Date / Version

25/02/2014

8.2. Manufacturing fertilizers

Title

Manufacturing fertilizers

Summary (10 lines)

In the farmland that surrounds a city fertilizers are going to be used in a conscious way, careful with the environment. In this sense good care of the ratio of raw materials to add and mix has to be taken into account, fulfilling both legal and environmental requirements and economic aspects. A score will be assigned based on the proximity of the proposed solution to the best one that satisfies the given "restraints".

Learning Objectives

What knowledge, competences and skills will students develop?

Environmental consciousness, economy, ability to decide or use the best solution picking from several possible ones based on several final requirements.

Discipline

Which engineering field (be as specific as possible) is it addressed?

Chemistry, agro chemistry.

The Task

Define exactly what is the problem that students will have to solve

Having as a target a given composition in individual components (e.g. 10% Fe, 20% N, 5% K, 10% P, etc.), the students will have to create a mixture made out of several raw materials available adjusting the required composition and best prize.

Background

What previous knowledge is required?

To perform the task reasonably well the students have to be aware of stoichiometry and handle easily concepts such as molecular weight, mol, mass to mol and vice versa conversions, etc. Also previous knowledge of spreadsheet usage is recommended.

Learning Activity Organization

What resources will be required? How is the learning activity organized?

The students will receive information about different raw materials, with their prizes, having a certain chemical composition that will be used to create the target "fertilizer". A set of legal and environmental requirements (ranges in final composition) that the fertilizer should meet will be provided to the students.

For a given final content of a certain element several raw materials will be available with their prices. For example to get the final Fe composition the student can select among $Fe(NO_3)_2$, $FeCl_3$, $FeSO_4$, etc.

For low educational level students only a limited numbers of raw materials will be supplied making easier to get the final solution.

An additional aspect that could be included into the problem is to consider that the raw

materials might be "impure" (not 100% active material). This will be ideal for student in higher educational levels.

Gameplay description

The game will start presenting the target: a certain amount of fertilizer of a given composition, and a set of tanks with different raw materials (these be needed or not) will be presented. Each tank will have the chemical formula, purity and price.

For the low level game the information will be reduced to the chemical formula (assuming 100% of purity), and also the number of "nutrients" (individual components N, P, K, Fe,etc.) might be reduced to 3. The number of raw materials will be also limited, only a raw material will contribute to a given nutrient.

Higher level games will include more "nutrients", purities different from 100%, several raw materials can add up to the final amount of same nutrient so the student will have to play also with the prices

Author / Organization

Roberto Tejero, Pascual Lahuerta / UV

Date / Version

28/03/2014 Version: 1.0

8.3. Purification of a natural gas field

Title

Title of the problem

Purification of a natural gas field

Summary (10 lines)

Give a brief description of the context, goals and expected results of the problem

The city needs a supply of energy from different sources. The recent prospections in the area have found a natural gas deposit that might provide enough energy to cover up to 20% of the city regular consumption. The analysis reflects a measurable content of sulphur-containing compounds mainly SH_2, OCS, CS2, and also CO2, that makes the gas unsuitable in the present conditions.

Gas purification involves the removal of the impurities from the gas streams. The primary operation of gas purification processes generally falls into one of the following

categories:
1. Absorption into a liquid.
    a) Basic solution
    b) Organic solvents
2. Adsorption on a solid
3. Permeation through a membrane
4. Chemical conversion to another compound

The student will have to study the content of the impurities in the gas and the highest limit of each contaminant that is allowed in the delivered gas. S/he will have to search the process or processes that can bring the level of contaminants to the needed values.

Part II. Optional and for higher education.
How to distribute gas to the whole city. This task will include the design of the pipeline and pump selection. The student can choose the pipeline material and diameter, in order to obtain the energetic requirements of gas pumping and choose the more appropriate pump. It could be included the calculations of investment and operation of pipeline and pump.

Learning Objectives

What knowledge, competences and skills will students develop?
They will learn how to work with different possible solutions to solve industrial chemical problems. They will learn how to work problems with different variables, economic cost of the process, cost of the installation, effectiveness of each process, etc.

Discipline

Which engineering field (be as specific as possible) is it addressed?
Chemical engineering

The Task

Define exactly what is the problem that students will have to solve
The student has to apply his/her chemistry and chemical engineering knowledge to reject first the options that do not have a relevant application to the problem. That will reduce the number of possible solutions to the problem.

The selected solutions will be analysed in detail. Each treatment will be giving the best result depending on the volume of the gas to be purified, and the partial pressure of the different contaminant, mainly SH2 and CO2 or the level of contaminant accepted for the final gas. This information will be provided to the student as part of the problem.

High school students will be asked to remove a single contaminant from the gas stream, namely SH2. They must find the most effective process from a selection that will be facilitated. They will have to use the economic criteria in the selection of the process.

For higher education students the economic aspects might be included. The goal will be to eliminate several contaminants, H2S, CO2, (and perhaps others) to permitted levels. They will have to choose from a wider selection of processes to perform this task and the economic evaluation will be a priority.

Background

What previous knowledge is required?

For high school students only SH2 and CO2 will be considered as contaminants. The knowledge required can be summarized in:

a) Recognize the acid character of SH2 and CO2.

b) Suggest the more convenient purification method base on the efficiency of the process, namely.

Higher education students are expected to be able to do further calculations of mass balance and economic optimization.

Learning Activity Organization

What resources will be required? How is the learning activity organized?

The student should carefully read the problem statement in which the removal of SH2 and CO2 content of natural gas is claimed.

The student will become familiar with the physical and chemical properties of the compounds and on this basis s/he will eliminate the proposed strategies that clearly are not going to produce the desired result.

Gameplay description

What should the students do to solve the problem?

At all levels, the student will receive information on the composition of gas in the reservoir as well as the major impurities, SH2-low level degree o SH2, CO2 and organic sulphur compounds in the upper level. They will also know the maximum level of contaminants allowed to deliver the gas.

Students will have information on the purification methods available to achieve the required results. The number of these techniques will be less for the lower level in order to facilitate the task.

If the problem is oriented to elementary students the student will have to find the method that is capable of performing the gas purification process in a more effective way with some economic aspects being considered.

Higher education students must evaluate, from the methods that lead to the removal of impurities, which are the ones that represent better value for investment. They will have to choose among a larger selection of methods to eliminate more contaminants.

All students will have access to extensive information which may include relevant and irrelevant data. This way, the student will have to select those data directly related to the problem.

The student will be asked to prepare a flow chart including the operations to be performed according to the selected strategy. To make the diagram the students will have template images that will be supplied with the tool.

Author / Organization

Amparo Cháfer, Pascual Lahuerta, Universitat de Valencia

Date / Version
06-04-2014 Version 1

8.4. Creating an earthquake-resistant city

Title
Title of the problem Creating an earthquake-resistant city
Summary (10 lines)
Give a brief description of the context, goals and expected results of the problem The city is located near a fault zone. The player will select the correct place by evaluating various factors like the expected earthquake gratitude, history of earthquakes in the area, soil types and combinations, nearness to the fault zone and decide on the type of construction, materials to be used for construction, maybe even the type of concrete to be used, cost of construction, number of floors etc. There may be archaeological, natural resources and other factors affecting costs and results. For example building the city on a strong ground may be cheaper but it can be far to natural resources. On the other hand building the city near water resources and a fertile land will be financially beneficial, but the player will have to construct stronger buildings and that will be more expensive. The player can also plan earthquake consciousness-rising activities for the people in the city, which will reduce the number of dead or injured people in a possible earthquake. At the end of the given time there will be an earthquake simulation to show success of the player. The aim is to provide the correct balance between an economic and social development of a city and the life guarantee of its inhabitants. This problem may be beneficial for civil engineering departments and also it will be very useful to make secondary school students, especially living at places near fault zones like Turkey, conscious about earthquakes.
Learning Objectives
What knowledge, competences and skills will students develop? Learning objectives will change according to target students. For secondary school students they will learn main types of soils, buildings and will have consciousness about earthquake protection. On the other hand for engineering students these main titles will include specific information of their classes. For example for civil engineering students building types category can be very detailed or for geological engineering students fault and soil types will have many sub-types.
Discipline
Which engineering field (be as specific as possible) is it addressed? Civil Engineering, Geological Engineering, Earthquake Engineering
The Task
Define exactly what is the problem that students will have to solve Students will have a map of various soil types and their mixtures. Choosing the correct soil type will not be enough to build strong buildings because that soil type may be near a fault zone or a river basis. So they will have to consider various factors including soil types, distance to fault zone, type, strength and cost of buildings, type of concrete, number of storeys,

nearness to natural sources, need for growth etc. They will also have a limited budget and will have to provide enough dwelling, social buildings, hospitals and roads for them. At the end of a given time an earthquake simulation will show how successful they are.

Background

What previous knowledge is required?

Soil types (like gravel, sand, clay, limestone etc.), foundation types, building types (reinforced concrete buildings, steel structures, adobe structures, light frame buildings, tilt-up concrete buildings, unreinforced masonry buildings), quality of cement, sand and rod, earthquake types and scenarios etc. The background knowledge depends on the target players of the game. If it is being played for secondary school students, the teacher will assign simpler factors but if it is played by civil engineering students, factors will more complex. Here specific problems will be created by teachers to be integrated in the game. For example "Formulation of a Clinker" problem proposed by the University of Valencia can be used at this level.

Learning Activity Organization

What resources will be required? How is the learning activity organized?

A PC or tablet will be used for individual students or group of students. The game can be played during the lesson or given to students as homework.

Smart boards can also be used by teachers to teach basics of protection against earthquakes from the point of civil engineering.

Gameplay description

What should the students do to solve the problem?

An earthquake has just happened in this city which was entirely devastated. Time to rebuild everything from ground up!

Game objective :

- You need to house X amount of people
- You need to place X amount of industry
- You need to place X amount of commerce
- You need to place X amount of hospitals, schools and social facilities
- You have X amount of budget
- You have X amount of time

You are presented with a color-coded map of the city. Fault zones are indicated, as are also the old sewer/water and electricity network. For the earthquakes, the type of soil of each zone is indicated, and nothing else (additional knowledge is required to understand which soil might be the most dangerous one).

You need to place houses and apartment buildings (4 possible varying in number of floors and materials, hence resistance), commerce and industry (4 of each) while at the same time minimizing the cost in space and money. The cost of placing buildings varies with the type and the exact placement (the more risky the zone, the cheaper it is). All buildings need to be linked both to the sewer/water and electricity network, which might be extended with a certain cost.

You can destroy a building you placed and you'll be refunded for the cost.

Winning condition: achieve placing all buildings within the budget. Withstand the final earthquake.

Author / Organization

Alper Metin / ANAKCPL

Date / Version
06.04.2014

8.5. MyMVNO's Access Network deployment

Title
MyMVNO's Access Network deployment

Summary (10 lines)
Give a brief description of the context, goals and expected results of the problem MyMVNO is a Mobile Virtual Network Operator company that has experienced a large increase of customers in recent years. Being a virtual operator, the company lacks any access infrastructure. In other words, the company does not have its own Access Network (AN) and it has to pay to other providers for using their infrastructure. Therefore, MYMVNO intends to deploy its own infrastructure and it wants to perform some simulations. The objective of the simulations is to verify that the company can deploy its own infrastructure while maintaining service quality (i.e. increasing operator's revenue) and reduce their operation costs. Students will be asked to perform the simulations deciding how to deploy the AN, basically which hardware devices to install and where (i.e. their locations). To do this, they must take into account the price, performance, power consumption, transmission capabilities and the suitability for each situation. The main idea is to cover the entire city without using other companies' networks. Students will use a game/simulation application to deploy the different elements on a map. The application should show the evolution of the AN along time, taking into account the behaviour of the system according to different scenarios: weather conditions, population increase, system breakdowns, natural disasters, etc.

Learning Objectives
What knowledge, competences and skills will students develop? The learning goal of this game is **to provide a view of how a mobile network works**. The game is introduced as an initial contact with the basics of the design of AN. Within the complexity of the infrastructure of mobile networks, ANs allow certain abstractions so a simple game scenario can be proposed. An AN, related to a cellular network, is the infrastructure that connects subscribers (e.g. mobile network users) to their service provider. These networks are divided into regularly shaped cells (i.e. hexagonal, square, round or some other regular shapes). A cell is composed by the area where service is provided and a cell site. Cell sites are where antennas and electronic equipment are placed. Students will have to select the hardware elements that form each AN from hardware lists. They also have to select the location of the cell sites. In this way, students will try the opportunity to learn about: • The deployment of AN taking into account how it impacts on the provided service and the budget of the company. • The sustainability of the AN over time, as long as the working conditions vary.

- The limitations during the deployment and configuration of AN:
  - Working frequencies must be shared between different operators.
  - The assigned frequency to a particular cell cannot be reused in adjacent neighbouring cells to avoid co -channel interference.
  - Weather and terrain conditions can also be part of the problem, so it would be interesting to interact with these conditions in the game.
- The difficulties of wireless communications: distance, obstacles, attenuations, etc. The formulas that define communication between antennas can be complex for high school students. Thus, the game will calculate all values and students may check how these factors impact on radio communications.

Discipline

Which engineering field (be as specific as possible) is it addressed?
Telecommunications (signal, channel access methods, mobile network architecture), Energy, Cost Management Skills, Physics

The Task

Define exactly what is the problem that students will have to solve
Students have a simple goal: the creation of an AN to offer the operator services to the inhabitants of the city. The game encourages students to be able to cover the entire city. This objective is composed by several secondary goals that have to be taken into account to successfully achieve the game. The deployment of the AN has to be done in stages with the funds provided by the operator. As time goes on, the money available for new installations will vary in function of the cell sites deployed, maintenance costs and the number of users connected to the new cells. If the AN generate losses or installing a new cell does not provide benefits to the operator the game will end.
Installation costs depend on the chosen equipment. Students may not exceed their current budget when installing new equipment. Therefore, students have to achieve a compromise between equipment quality, costs and potential new users.
The number of users is very important for the operator. Students must try to increase the number of users for each new cell. As discussed above, the installation of a cell that does not add new users (i.e. increase the operator's revenue) will force the end of the game.
Students should be especially careful when assigning frequencies to cells. Misconfiguration can make large areas inoperative, which affect at least two adjacent cells. This will reduce the number of current users. This impact negatively on the profits of the operator.
In addition, the distribution of people will vary over the time (e.g. weekend, holiday seasons). Climate changes could occur and the coverage radius of the cells will fluctuate. These two factors can affect both positively and negatively to the revenue of the operator.

Background

What previous knowledge is required?
We intend to offer a gameplay which will only require the ability of point-and-click, and some mathematical knowledge (i.e. estimate equipment costs). The concepts underneath this game are difficult to achieve even for a university student. For this reason, all data should be automatically calculated by the game, so students will only have to test things and check what

happens.
It may be interesting to have knowledge of physics to understand the behaviour of antennas in the different scenarios.
Further explanations can be done after the game is played, answering students' questions.

Learning Activity Organization

What resources will be required? How is the learning activity organized?
Resources: computers to play the game/simulation
Preparation
Students should be organized in groups. After that, we propose two ways to start the game. In both cases, and if students are in high-school, a university student could be involved in each group, acting as a tutor. The game presents several different scenarios. Each scenario defines a city game with different characteristics. The purpose of the game is to deploy an AN to cover the whole city.
Quick Mode
A classroom with 25 students could be organized in 5 different groups; each group will play a different scenario (i.e. each group will play with a city from different countries: Portugal, Spain, Italy, Greece, and Turkey). All the students will receive a common introduction to the problem.
Each group works on the city and at the end of the experience they show their results (i.e. coverage with a limited budget, number of users served, etc.), decisions (i.e. which equipment was selected and why) and design (i.e. where was the cell sites placed) to the rest of the classroom in a presentation. After all, each group can compare the differences found among the other groups.
Alternative mode
Students could be organized in groups. All groups will play the same scenarios. Students can play one, several or all the scenarios in a row. By playing on more than one city, students will perceive the differences between cities and how these differences impact on their final decisions. At the end, students can discuss which where the crucial factors for each city, and compare the differences between cities (from the point of view of a mobile network operator).
There is also the possibility of creating a set of score lists for each city according with some goals. Each group of students will have a position on each list; the weighted average of the position of each list will be its score. Weights should be assigned after the performance of some test. The fewer score a group has, the better. We propose the following goals:

- A sorted list ordered from less to more by the money spent by the group,
- A sorted list ordered from more to less by the percentage of city that is served,
- A sorted list ordered from more to less by the revenue of the operator,
- A sorted list ordered from less to more by the time used to end the scenario, and
- A sorted list ordered from more to less by the number of potential users.

After match
Regardless of the used mode, at the end of the game teachers can go into detail on those points that were most striking for students. Teachers can explain how to create a wireless link between two points, enumerate different types of antennas and their radiation modes, present simple mobile communication structures as GSM or GPRS or exhibit more complex architectures, like UMTS or LTE. Teachers can also explain which types of channels are established for mobile communications, authentication types, encryption methods and

pricing. Teachers can explain how several terminals are connected to the same network and share its capacity. For example, teachers can explain how to FDMA (Frequency Division Multiple Access) works and can define when to use a CDMA (Code Division Multiple Access) and how it works.

Framework specification

City Characterization

The city is the game zone. All the cities have the following parameters:

1. Inhabitants characterization: the game must have information related to the inhabitants of the city. The main parameters should be:
   1.1. Distribution of the people in the city: the population density should be provided to note the effect of the limit of users allowed on each cell.
   1.2. Distribution of the inhabitants' age: that is because younger peoples use more mobile devices than older people.
   1.3. Usage habits according with the inhabitants' profile: the usage profile can vary according with the age, job and hobbies of the inhabitants of each zone of the city. A first approach can be done by identifying school zones, business streets and malls.
   1.4. Usage habits along the week: usage patterns can vary according the day of the week. During the week, there would be more usage on business streets. On the other hand, the usage on entertainment streets is increased at weekend.
   1.5. Mobile phone: each potential user has the same mobile phone. The characterization of the mobile will affect the communication range of each inhabitant. Using the same mobile for all users simplifies range calculations.
2. Geography characterization: the terrain is an important factor to take into account.
   2.1. Soil elevation: higher places are better to place antennas.
   2.2. Position of the mountains in the city: mountains can prevent to service areas behind mountains.
3. Weather characterization: climatology directly affects radio communications. The storms are not taken into account in this game, although storms affect negatively to radio communications. The game should know the annual distribution of rainfalls, so an accurate simulation could be done.

Mobile Network Cell

The second most important elements in the game are the mobile network cells. These cells will compose the AN of the city. The parameters of a cell depend on the selected equipment chosen by the students, i.e. the cell site. A cell site could be represented on the city map as a point that can be placed wherever the student wants by a drag&drop system.

A cell site is composed by:

1. Antenna: the antenna is the element in charge of establishing wireless connections with the users' devices. The type of the antenna can be omitted for this game. An antenna can be characterized by the following parameters:
   1.1. Price: how much cost the hardware and its installation.
   1.2. Power consumption: determines the necessary energy for a normal work.
   1.3. Radiation: we propose a radial radiation model.
   1.4. SNR (Signal-to-Noise ratio): defines the minimum difference between the power of the received signal and the power of the incoming noise to achieve a successful identification of the incoming signal. The lower SNR, the better immunity to noise and the more expensive.

1.5. Power gain: this factor determines how strong a signal is amplified once is transmitted by the antenna.
1.6. Bandwidth: frequencies on which the antenna can transmit.
1.7. Number of maximum client devices: number of mobile phones that can be connected to the cell at a time.
1.8. Number of maximum active client devices: number of maximum mobile phones that can be active (sending/receiving information) at a time.
1.9. Range: distance from the antenna with enough coverage to establish a radio communication with mobile devices. This value is dynamic; it depends on the geography and the weather parameters. For this game, this parameter can be calculated with the SNR parameter, the power gain, and the city parameters.

2. Communication station characterization: this hardware controls the communications inside the cell and can send information to the mobile network backbone.
   2.1. Price: how much cost the hardware and its installation.
   2.2. Power consumption: determines the necessary energy for a normal work.
   2.3. Number of maximum client devices: number of mobile phones that can be connected to the cell at a time.
   2.4. Number of maximum active client devices: number of maximum mobile phones that can be active (sending/receiving information) at a time.

Additional Parameters

The game should take into account the initial budget provided by the operator. This budget sets the limit of money that the students can invest into the early stages of the AN deployment. Additionally, the operator also has a set of frequencies that can be used on the cells. This set of frequencies is limited, so students must reused the frequencies along the AN.

Gameplay description

Students must deploy a set of cell sites to create an AN on the city. Initially the city has no cell sites from our operator. At the beginning, students should check inhabitants distribution, weather statistics and geographical information, and plan where to place cell sites.

Once they have a global idea of the initial conditions, they should check the available equipment. There is a wide range of antennas and communication stations, so students must find those how fit their needs. Students must select one antenna and one communication station to create a cell site. Once the equipment is selected, the students must place the cell site on the map. They will see immediately the coverage area of cell. This area will have a circular shape, where the centre is the cell site and the radius will be the antenna's range that is dynamically calculated (see Framework specification). As soon as the students install a cell site, they will be able to check how many users affects this installation, how the revenue of the operator is increased/decreased and how much will cost. Once students have placed some cell sites, the simulation can be launched. From this point, days will pass slowly and students will see how the range of the cell fluctuates. Operator's revenues will be increased according with the area served and the amount of users on that area. The limit of new users depends on the cell site capabilities and the inhabitant's information. Once installed, cell sites will be active, so the power consumption will reduce the budget. Students will have to take special care to increase the coverage area while reducing the power consumption to have more money and more users. During this process, students must reach a compromise between the maximum number of clients and the cost of the infrastructure.

Author / Organization
Martin Llamas, Juan González Tato and Manuel Caeiro.

Date / Version
31/03/2014

8.6. Operation of industrial activities.

Title

Title of the problem

Operation of industrial activities.

Summary (10 lines)

Give a brief description of the context, goals and expected results of the problem

The community needs to have an industrial base to generate jobs and provide needed consumer goods. This includes installations of various types of industries, such as bakery, slaughter of animals, paint factory, winery, manufacture of ceramic products, vegetable processing plants, dairies, etc.

The student will propose the most suitable method to reduce the residues generated by the industry, so that they meet the environmental requirements of the community. Otherwise there may be an administrative penalty or even a temporary closure of the industry.

In the treatment of the industrial waste that will be generated, the regulations will be different if the industry is installed in an industrial area, with services provided by the community, or in a non-urban area. In the last case these regulations will be stricter.

Learning Objectives

What knowledge, competences and skills will students develop?

A detailed knowledge of the current environmental requirements for industrial activities, which apply equally to all countries of the European legislation.

Discipline

Which engineering field (be as specific as possible) is it addressed?

Civil /chemical engineering

The Task

Define exactly what is the problem that students will have to solve

The student receives information on the characteristics of the wastewater generated by the industry, volumes and composition (chemical demand of oxygen, DQO, suspended solids, total N, total phosphorus, conductivity, pH).

The student will know what the approved parameters are for the spill, which may vary depending on the location of industry. With this information, the student must select he appropriate treatments to make the emissions comply with the environmental regulations.

In a first step we might only develop the industry management section, leaving the installation requirements related to the second phase, if this task is interesting.

Background

What previous knowledge is required?
A general knowledge of the physic-chemical properties of the products generated in each case at the factory. Their degree of environmental contamination and the operations that can be performed for their destruction or isolation.

Learning Activity Organization

What resources will be required? How is the learning activity organized?
The student will receive a description of the activity that takes place in the industry. He will also have the information on:
- Current regulations regarding waste disposal (usually water).
- Possible treatments to be performed to achieve the objectives.

At an elementary level of the problem, a list with the nature of the waste generated by the industry as well as the properties and hazards will be provided.
At a higher level, this information might be selected by the student from a longer list that will be provided.

Gameplay description

What should the students do to solve the problem?
In a first stage, the student will study what are the characteristics of the factory, its manufacturing process and, depending on the level of the problem, what are the wastes generated and their characteristics.
The student will study the regulations on maximum permitted levels of pollution and he will compare with those emitted by industry, an information that will be provided by the problem. From this point, the student will present a work process to reduce pollutants, if the level of water pollution arising from the process exceeds the values established by the regulations. There will be a library with detailed information that will guide you on the tasks to set each parameter. It is noteworthy that the emission of pollutants above the maximum permissible values carries a financial penalty but a considerable reduction below these values may be accompanied by a reduction in municipal taxes and therefore an economic benefit for the company.
In the procedures implementing waste reduction we can establish two levels of difficulty.
On a basic level the correct application of a procedure will entail directly the reduction of such waste to acceptable levels. At a higher level the student will have to use a variable reagent dosage in order to achieve the correct values of the effluent. Bearing in mind that processing involves labour cost, labour time and reagent consumption may also be relevant. The level of detail with which these procedures are designed will be determined by a balance between the difficulty of implementation and relevance of the process tool.
Additionally at a higher level to optimize a parameter there might be more than one procedure. The student will have to decide what kind of alkali should be used when adjusting the pH, or chemical or biological type of treatment is most suitable for organic waste destruction and if it is possible to implement it.
In a final step the student will construct a diagram using some icons, each of which represents an operation, filtration, settling, pH adjustment, organic waste destruction, etc. The diagram must represent the proposed operations in the correct order. These icons are standardized and available from software for the design of industrial processes.
Each time the proposed solution is not acceptable, the program will send a message about the consequences of discharging sewage in the proposed conditions. We think this can help improve the environmental awareness of students, especially those from lower educational levels.

Author / Organization
IQD Eduardo Moreno, Pascual Lahuerta, UV

Date / Version
31/03/2014 Version 1.

8.7. Code-Living City

Title
Title of the problem **Code-Living City**
Summary (10 lines)
Give a brief description of the context, goals and expected results of the problem The game presents a future city as a living entity that is able to control some of its public services. Particularly, streets are journeyed by automatic buses, taxis and other vehicles that are driven by automatic systems. Students will be required to program these systems, so the vehicles move around the city according to their planned routes to serve the city inhabitants. Students must model the behaviour of these active elements by using programming sentences. This will bring them the opportunity to experiment with programming elements. For example, students will model the behaviour of a bus journeying its route; or will create algorithms to make taxis to offer their services to the inhabitants of the city, etc. The game can be composed by many stages. The goal of the game is to fulfil the requirements of each stage until all stages are done. As long as the stages are completed, students will learn basic concepts of programming languages oriented to Object-Oriented Programming languages (OOP). So, it is expected that students will be able to learn programming basics while competing against their peers.
Learning Objectives
What knowledge, competences and skills will students develop? The purpose of the game is to present some computer programming fundamentals. This game can be used to introduce imperative programming and Object-Oriented Programming (OOP). A new student on programming will learn basic concepts: algorithms, variable management, conditional and loops, class and object definition, etc. It is neither the purpose of this game to teach how to create a real program nor to teach to use a particular language. Neither compiler nor real code will be used.
Discipline

Which engineering field (be as specific as possible) is it addressed?
Computer programming fundamentals, Algorithms, Boole's Algebra

The Task

Define exactly what is the problem that students will have to solve
Students will have to complete scenarios sequentially. To advance to the next stages, a student must complete the objectives of the current stage. Each scenario pretends to teach or reinforce different programming skills. The scenarios will increase in complexity and allow students to improve their skills.
To complete each stage, students must use knowledge and skills learned on previous stages and apply the concepts presented in the current stage. The game allows students to see effects triggered by the sentences written by them. In this way, students will be aware of the implications of theirs decisions.

Background

What previous knowledge is required?
None previous knowledge is needed.

Learning Activity Organization

What resources will be required? How is the learning activity organized?
Resources: computers to play the game/simulation
Students can play alone or in groups. They only need a computer to run the game. A teacher with programming skills can assist students with some explanations or answering questions. Once students have played several stages, students can share their views and discuss those points.

Framework specification

What parameters define the scenario?
The game engine should allow students to join some predefined blocks with particular instructions. In our case, the blocks are pseudo-programming code. The blocks of pseudo-code should be read by the engine to check its syntax and to execute them. The execution of sentences can trigger alert messages (e.g. to report a bug in the code) or an action performance by an active element on the map (i.e. bus, taxi, or another element). After the execution of all the lines, the engine has to verify that the stated objectives on the stage are met. If all the objectives are met, the student can advance to the next stage. Otherwise, a message explaining the errors should be displayed, to help students to understand their mistakes.

The streets must be identified and highlighted on the map. The streets have to be modelled, so the engine of the game will be able to move items correctly through the city streets. To simplify the modelling of the streets, the engine can ignore pedestrian streets and streets always have both traffic directions. For the last stages, more elements can be posed: traffic jams, streets block, etc.
The engine should be able to add graphical items on the map and move them through streets following students' instructions. These elements are buses, taxis and other elements needed

to perform actions. The game can be improved by adding new elements to its repository. These elements should be related to city services or maintenance tasks: police department, firefighters, etc. New stages could specify that use these new items.
The game must provide a set of predefined classes that represent important active elements of the city. Here we present a brief example of the possible active elements present:
Inhabitant class
Properties: name, passport, age, hobbies, etc.
Methods: hello, say, handshake, etc.
Driver class: extends Inhabitant class
Properties: driver license, etc.
Method: drive, charge, etc.
Vehicle class
Properties: fuel, driver, plate, etc.
Methods: goForward, turnRight, turnLeft, startEngine, stopEngine, stop, etc.
Bus class: extends Vehicle class
Properties: number of passengers, etc.
Methods: openFrontDoor, closeFrontDoors, openBackDoor, closeBackDoor, pickupPassangers,
Taxi class: extends Vehicle class
Properties: taxi license, etc.
Methods: isAvailable, isOnDuty, pickupPassanger, etc.

Gameplay description

What should the students do to solve the problem?
First stage: Class and object definition and differences. The first stage is a tutorial that presents the terms: class and object. A class defines a set of objects that has the same specification. All objects from the same class share their characteristics, semantic and restrictions. As an example, the game will present the class bus and describe its methods and properties.
These methods correspond to the behaviour of the vehicle: start engine, go forward, turn right, etc. Each actual bus on the city is an object of the class bus. From this point of view, all actual buses have the same methods. This stage presents as example the sentences to move a bus along a street (i.e. startEngine - goForward - stop - stopEngine).
The properties describe the status or the information contained on an object. The buses may have different values assigned to their properties, this make buses different from one to another.
Second stage: The game tells the students to model a bus route as shown on the image. Students must write the code to achieve the bus to complete a particular route on the map. When the code is written, the game will test student's sentences.
Third stage: On the previous stage, a student made a valid bus route. Now, the student must modify the previous sentences to stop the bus on each bus stop.
Fourth stage: This stage will present the conditional actions. This stage explains how to create conditions and how to execute conditional sentences. Some information about Boole's algebra is provided. On this stage, the student must modify the bus behaviour to stop on each bus stop only if there are people waiting at it or any passenger wants to go off the bus.
Fifth stage: This stage will present the loop structure 'for'…
... many stages later …
Final stage: The game will gather all the information created by the students to complete the

stages and compose a new class. This final class will be a class that defines the entire city. The purpose of this stage is to prove that our game zone, the city, can be an instance (i.e. an object) of a class. This stage will state that we can create a class of a city, a state, a country, and so on.

Author / Organization
Martín Llamas, Juan González Tato and Manuel Caeiro.

Date / Version
31/03/2014

8.8. Building, setting up and testing a Local Area Network

Title
Title of the problem Building, setting up and testing a Local Area Network
Summary (10 lines)
Give a brief description of the context, goals and expected results of the problem Actually only software with fee or electronic calculator are available for students that want to improve their theoretical and professional skills in the networks building and setting up. The fundamental proposal's goal is the development of a serious game which allow students to acquire skills and competencies in the informatics sector to be applied in the real world. By playing real-life situations students have to build a Local Network Area (LAN), set it up and test it using specific knowledge inside a simulated and protected work environment. Thank to this proposal the game will consent students to select at least 5 problems where different type e dimension of net, subnet and device have to functioning in a Local Network Area. Furthermore students will have the opportunity to set up new problems by themselves and then try to solve them.
Learning Objectives
What knowledge, competences and skills will students develop? Thank to this game students will strengthen knowledge regarding decimal and binary numeration, will develop skills and competences regarding how to build a Network, how to change its features, how to identify a IP in a Network, how to create LAN, how to divide a net in subnets, how to use correctly devices as hub, switch, bridge, router.
Discipline

Which engineering field (be as specific as possible) is it addressed?

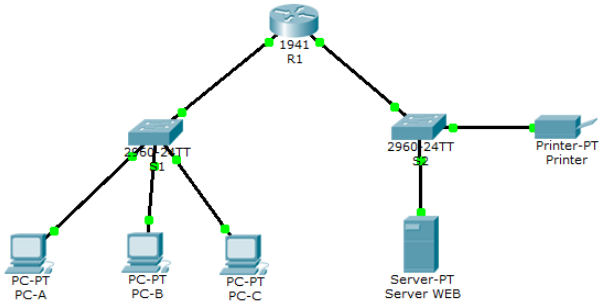
Informatics engineering.

The Task

Define exactly what is the problem that students will have to solve

Example 1 – Problem 1
A client asked you to:

1. Set up the following type of Network, using Router and Switch:



2. Configure the devices as indicated in the following tab

Device	Interfaccia	Ipv4	Subnet mask	Gateway	DNS
R1	G 0/0	10.0.0.254	255.0.0.0		
R1	G 0/1	192.168.0.254	255.255.255.0		
Server web	F 0	192.168.0.253	255.255.255.0	192.168.0.254	
Printer	F 0	192.168.0.252	255.255.255.0	192.168.0.254	
PC-A	F 0	10.0.0.2	255.0.0.0	10.0.0.254	192.168.0.253
PC-B	F 0	10.0.0.3	255.0.0.0	10.0.0.254	192.168.0.253
PC-C	F 0	10.0.0.4	255.0.0.0	10.0.0.254	192.168.0.253

3. Verify that all the devices can ping themselves

4. Active on the Web server the http service and insert the following HTML code in the page index.html.

```
<html>
<head>
<title>e-city School</title>
</head>
<body>
<h1 align="center">Welcome</h1>
</body>
</html>
```

5. Set up on the Web server the DNS service in order to make the website reachable from the PC (A,B,C) pressing www.e-cityshool.eu in the browser URL.

Example 2 – Problem 2

A client have to solve different type of issues:

1. Choose the IP class (A;B, C, D, E); an IP is assigned to you. You have a network with 2 subnets linked by a router; Identify the subnets IP giving the address of every subnet and host;
2. You have the IP 198.2.3.0: how many subnets with 15 clients can you build? Then identify the subnets IP giving the address of every subnet and host;
3. You have the IP 198.2.3.0: you have a network with 7 subnets; the first three have 4 subnets each; the other four have 3 subnets each; the subnet 6 and 7 are linked by a bridge. Identify the subnets IP giving the address of every subnet and host;
4. You have the IP 198.2.3.0: build 5 subnets linked by a router and indicate how many final clients could you host in the network; then implement a NAT mechanism in the router so you can assign dynamically the IP to the PCs of the LAN which they need.

Background

What previous knowledge is required?

Subnetting processes, decimal and binary numeration, IP numeration for nets and subnets, functioning of router, switch, hub, features of main devices used by common users (tablet, pc, laptop, etc).

Learning Activity Organization

What resources will be required? How is the learning activity organized?

The serious game could be played by:

- Individual student with a laptop or a tablet with internet connection
- guided groups of 5 students each with a laptop or a tablet with internet connection (for class of maximum 25 students)

Gameplay description

What should the students do to solve the problem?

The students is a IT specialist, sent to an enterprises by his boss. To solve the problem the student should essentially absolve the requested of his client: building a network, setting it, identify the answers to the question the client makes. The end of the problems consist in verify and test the solution. When the solution tested goes well the client will be happy and he will congratulate with the student.

Author / Organization

Andrea Bianchi, Duilio Cominini, Sergio Tasca, Claudio Priori from Fondazione Ikaros.

8.9. Buses to the University and Beyond

Title
Title of the problem Busses to the University and Beyond
Summary (10 lines)
Give a brief description of the context, goals and expected results of the problem The problem involves the need to provide bus services to attend university students, and other users: K-12, high school students and public in general. Each one of these users has different timetables and travels. The objective of the problem is to optimize the use of buses, supporting all people with the minimum number of buses and drivers. We want to reduce the carbon footprint also: if not enough buses are provided, the people will use their own cars and the pollution will increase. The game/simulation application will show a particular city with some schools and roads. Students need to decide the routes, the number of buses, the timetables, etc. The application will calculate the number of cars needed, the pollution produced, etc.
Learning Objectives
What knowledge, competences and skills will students develop? To organize resources and timetables To optimize the use of resources (human and material)
Discipline
Which engineering field (be as specific as possible) is it addressed? Logistics
The Task
Define exactly what is the problem that students will have to solve Design the bus routes and timetables
Background
What previous knowledge is required? Nothing specific
Learning Activity Organization
What resources will be required? How is the learning activity organized? Computers to play the game/simulation Students can be organized into groups and assigned different scenarios corresponding to different cities: Porto, Vigo, Bergamo, Thesalonia, Ankara.
Gameplay description
What should the students do to solve the problem?
Author / Organization
Manuel Caeiro Rodríguez/ University of Vigo Martín Llamas Nistal/ University of Vigo Andrea Bianchi/ Fondazione Ikaros Lucio Faré/ Fondazione Ikaros

Date / Version
February 25th, 2014/2.0

8.10. Formulation of a Clinker

Title

Title of the problem

Formulation of a Clinker

Summary (10 lines)

Give a brief description of the context, goals and expected results of the problem

The Portland cement clinkers are mainly obtained by calcination at temperatures between 1350-1450 °C of mixtures of limestone and clays. It is a granular, hard and grey material. In its composition fall silicates, aluminates and ferrites of anhydrous calcium. Clinker is the main component of Portland cements.

The raw materials used in the preparation of clinker are of two types: i) Limestone rocks with high content of CaCO3 that by thermal decomposition originate the basic oxide CaO and ii) Clays, sandstone and iron oxides by thermal decomposition generate acidic oxides, SiO2, Al2O3 and Fe2O3.

Starting from certain raw materials the main constituents of clinker are formed:

Calcium silicates SiO2.3CaO and SiO2.2CaO, calcium aluminate Al2O3.3CaO, calcium ferrite Fe2O3.2CaO and calcium aluminoferrite Fe2O3.Al2O3.4CaO.

Learning Objectives

What knowledge, competences and skills will students develop?

Students will develop the ability to perform material balance calculations.

They will learn more about the cement manufacture.

Discipline

Which engineering field (be as specific as possible) is it addressed?

Chemical and civil engineering

The Task

Define exactly what is the problem that students will have to solve

Given the composition of the raw materials in terms of content on different oxides, the student must calculate the composition of the resulting clinker. Knowing the properties of each of the constituents of the clinker rate of hydration, mechanical strength and chemical resistance (durability), the student must establish the suitability of the clinker for manufacture of cement of certain features.

Background

What previous knowledge is required?

They need basic chemistry knowledge. The student must be able to perform stoichiometric calculations.

Learning Activity Organization

What resources will be required? How is the learning activity organized?

The student receives full information on the process of formation of clinker and the components formed in this process. They also receive details of how is contribution of each component of the clinker to the properties such as mechanical and chemical resistance, etc..

Gameplay description

What should the students do to solve the problem?
Students will begin studying the information provided on the clinker formation process, the various components thereof and the properties associated with each of these components. He will receive a selection of raw materials with an established composition and certain amount. The student will have to perform the required calculations to determine what percentages the different components of clinker will be obtained.(Optionally he will can have access to an example of such problem properly completed).
In view of the results they must establish the main properties of the resulting cement.
Additionally, higher education students will be asked to propose modifications of this formulation in order to increase certain property of the resulting cement.
Eventually, and also for higher education students, raw materials containing more than one acidic oxide in the composition, might be incorporated.
A final option is to add economic aspects adding a prize to each of the optional raw materials.

The use of an excel page can be suggested to the students to perform the calculations. For lower educational levels such file might be included in the tool.

Author / Organization
Jordi Payá and Viki Borrachero, UPV; Pascual Lahuerta, UV;

Date / Version
31 March 2014

8.11. Traffic lights

Title
Traffic lights
Summary (10 lines)
The traffic lights in our city are truly lacking. Many citizens are complaining about the many traffic jams our city experiences. The city hall has decided to tackle the situation by redefining all the timing for all the traffic lights downtown. You are tasked with designing the new timings and determine how the traffic lights will now work, on a per hour basis. You'll be provided with a map of the current traffic lights and their behaviour and also with a simulation of the typical car traffic per day in our city.
Learning Objectives
What knowledge, competences and skills will students develop?
Discipline
Which engineering field (be as specific as possible) is it addressed?

The Task
Define exactly what is the problem that students will have to solve
Background
What previous knowledge is required?
Learning Activity Organization
What resources will be required? How is the learning activity organized?
Gameplay description
What should the students do to solve the problem

Author / Organization

Date / Version

8.12. Create a network of food banks for social assistance to the population

Title
Title of the problem Create a network of food banks for social assistance to the population
Summary (10 lines)
Give a brief description of the context, goals and expected results of the problem The community welfare offices confirm that, at the present time, 3% of the population is in poverty. The aim is to create food banks to periodically distribute batches of food to the needy. The project has to establish the needs to cover 50% of a balanced diet, based on a list of basic food, rice, vegetables, milk, water, etc.. For the population of children bellow one year specific food will be provided based on milk and etc. To simplify the problem, the daily calorie intake and the carbohydrate/protein ratio in the supplied batch will be fixed. Known population of the city and the storage capacity of the standard storages, the project can address the calculation of the number of required deposits and the

distribution, location and details of food distribution. Distributed food can come from private donations or government subsidies. The entrance to the food bank supplies may vary over time. A different summer and winter diets can be established. The project can be combined with the creation of urban gardens in which low-income citizens can grow some of their fresh foods, fruits and vegetables, legumes. Might involve setting the size of the lots and the type of crop in each season. This second version would be suitable for an orientation of agricultural engineering and will require more technical knowledge.
Learning Objectives
What knowledge, competences and skills will students develop?
Discipline
Which engineering field (be as specific as possible) is it addressed?
The Task
Define exactly what is the problem that students will have to solve
Background
What previous knowledge is required?
Learning Activity Organization
What resources will be required? How is the learning activity organized?
Gameplay description
What should the students do to solve the problem?
Author / Organization

Date / Version

8.13. Wind Farm Location (Optimization) Problem – Random Choice? Your Loss

Title
Title of the problem *Wind Farm Location (Optimization) Problem – Random Choice? Your Loss*
Summary (10 lines)
Give a brief description of the context, goals and expected results of the problem *This is a good example of how important optimization problems are in real life. The understanding of optimization problem solving techniques like linear programming is a key aspect of an engineer oriented student.*

On the following example the optimal solution for total cost minimization of installation is €525k while randomly choosing A+B+C+D results on a spent budget of €767k!

Example
Due to E.U. regulations and environmental and sustainability concerns the city has to start producing energy from renewable sources. This implies in this phase the installation of at least 10 MW on wind farms. The maximum allocated budget is €780k.
Wind probabilities studies as economical ones shown the following suitable places for installing the wind farms.

Place	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
Suitable Capacity (MW)	*2.2*	*4.4*	*1.1*	*5.2*	*1.5*	*1.5*	*2.2*	*4.8*	*1.0*
Cost (k€)	*100*	*244*	*22*	*401*	*88*	*84*	*101*	*302*	*52*

Due to environmental and city planning issues A and B are mutually exclusive choices.
Which of the places should the city choose in order to minimize the total cost of installation?

(Other possible questions:
Which of the places should the city choose in order to maximize the total installed capacity?
Which of the places should the city choose in order to minimize the total number of wind farms?)

Learning Objectives

What knowledge, competences and skills will students develop?
Optimization Problems Importance
Kinds of Optimization Problems
Optimization Problem solving techniques
- *Linear Programming*
- *Linear Binary Programming*
- *Graphic solving Understanding (for small problems)*
- *Computer based Solving Techniques (e.g. Excel Solver)*

Discipline

Which engineering field (be as specific as possible) is it addressed?
Mathematical Reasoning while focusing on optimization problems (linear programming using a binary form) – operational research.
Electrical Power Systems optimization problems

The Task

Define exactly what is the problem that students will have to solve
The problem is a type of a typical assignment problem in operational research (it can be adapted in many ways and can be solved and evaluated by the game itself).
Students will have to study, understand and identify the mathematical model of the problem. Then they shall see typical solving strategies for typical problems.
The basic form of solution the students have to present is: Decision Variables (What locations are chosen); Objective Function Value (Obtained cost);

Background

What previous knowledge is required?
Basic Mathematical High School knowledge
Operation Research Basics
Linear Programming
Useful:
At least linear functions (y=mx+b) comprehension and 2-dimensional graph.
Excel Solver

Learning Activity Organization

What resources will be required? How is the learning activity organized?
The player will have to spend a little time solving the problem of his city as the city budget is tight. As a support tool players would normally use Excel Solver (or any other equivalent one) to find the best suitable solution.
Once the players go deeper in operation research basics a widely range of optimization problems can appear. If this subject is lectured before in classes (or at the same time) this applied learning activity can help to engage the students:
This kind of problem can really make a difference in the game (as in real life) for the players as the city budget can largely vary as a better or worse solution is chosen.
This kind of problem can be an "unlockable" one. For instance the wind power plant technology can be unlocked only when an optimal solution is achieved.

Gameplay description

What should the students do to solve the problem?
To understand what it is asked
Identify an operation research problem
Identify the Decision Variables
Identify the Objective Function
Identify the restrictions
->Formulate the problem mathematically
Choose the appropriate solving technique and tool (e.g. computer based)
Critical analysis of the solution
Submit the solution in the game
The game evaluates the solution and deducts (if it is a possible solution) the money balance from the city account -> The Wind farms appear.

Author / Organization

Fábio Nogueira

Date / Version

24-02-2014

8.14. Traffic

Title

Traffic

Summary (10 lines)

Citizens are dissatisfied; the traffic jams are getting uncontrollable in the city!
The entire road network and public transportation needs some thinking. Sadly the soil here contains some water table which makes digging a subway an impossible endeavour.

Learning Objectives

What knowledge, competences and skills will students develop?

Discipline

Which engineering field (be as specific as possible) is it addressed?

The Task

Define exactly what is the problem that students will have to solve

Background

What previous knowledge is required?

Learning Activity Organization

What resources will be required? How is the learning activity organized?

Gameplay description

What should the students do to solve the problem?

You can influence on the existing traffic lights or place new ones, manage and build new bus lines. And parking zones for cars too. Pedestrian zones are not going to be created by the user directly, they will be implicitly done when parking lots are set outside of a certain zone and bus services join the zone and the car park. Maybe we could add traffic signs such as one way traffic, constraining even more the car flow or maybe special bus-oriented traffic lights. The traffic is simulated on 4 period basis: morning, afternoon, evening and night. The objective of the game is too having the citizen reach a certain happiness level.
The period will be presented as states, represented by an icon (rising sun, full sun, setting sun, moon) between which the user can navigate through a pair of arrows. Inside a period, the user can set all the parameters he wants and then presses a launch/play button to start the simulation and see the result happen.
Winning conditions : reach a certain degree of happiness for the population. The condition to raise happiness is making the traffic more fluid.

Author / Organization

Date / Version

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