A GAME-BASED, ACTIVE LEARNING APPROACH FOR BUILDING 21ST CENTURY SKILLS IN ENGINEERING AND ECONOMICS HIGHER EDUCATION

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Abstract

This work presents an active, game-based learning approach for building problem solving capacity among higher education (HE) students in the combined fiends of engineering and economics. This is achieved through problem and project-based digitally-enabled educational design. A digital game-based, active learning environment is under development that challenges students to collaborate, think innovatively, and weave diverse knowledge towards introducing solutions to non-trivial learning scenarios inspired by 21st century needs, exposing them to real-world industry practices while also building project and time management skills. The intervention exposes students to open-ended educational activities that are implemented in teams through role playing in a multi-user environment. While the team strives towards a common goal, each student has different objectives that may be conflicting with those of other team members as the group uses common resources. At the same, students build soft skills including collaboration capacity, critical thinking, and entrepreneurial mindsets. Digitally enabling the problem-solving process effectively increases class interaction, communication, knowledge exchange, peer learning, and collective skill building contributing to the development of desirable transversal skills. Gamifying the problem solving process promotes active student engagement in learning through a sense of mission, a sense of affiliation, healthy competition, rewards, and social recognition by peers among other mechanisms.

Keywords: innovation, technology, research projects, engineering, economics, active learning.

1 INTRODUCTION

Today's young generation will be called to address urgent 21st century challenges such as sustainable growth, quality in education, sustainable natural resource management, mitigating climate change, addressing natural risks, fighting poverty, informing global health, and more. The challenges that our global society faces are daunting and the design of solutions is pressing for promoting well-being and equity. Potential viable interventions often stem from a combination of engineering and economics knowledge; scientists are called to introduce effective socio-technical interventions within specific budgets.

Solutions to modern challenges do not stem from the deployment of knowledge from a specific theme; rather, they require the integration of knowledge from diverse scientific areas. In the emerging 21st century world, education needs to be itself re-engineered in order to build the knowledge, skills, and mindsets that young adults will need to become leaders in designing integrated, effective, and equitable solutions that ensure quality of life and social cohesion.

Engineering technology and business process innovation are on the cutting edge, evolving at a very past pace; solutions that are considered groundbreaking at a point in time may become obsolete only a few years after their introduction as the result of their replacement by more powerful, flexible, and suitable approaches. The biggest challenge facing HE today is not simply building the foundational knowledge of young professionals; it needs to shape young adults that are problem solvers, high level and critical thinkers, innovators in the face of rapid evolution of technology and business processes, effective collaborators in multiple social contexts and large groups, and, most importantly, capable of learning independently throughout their lives in order to remain at the forefront of their fields.

This work presents the HERA learning intervention that applies active learning design to build problem solving skills among higher education (HE) students in engineering and economics [12]. HERA addresses the interdisciplinary needs of HE in the fields of engineering and economics on making available educational offerings that help build the high order problem solving skills required by 21st century society for addressing complex emerging challenges through solution that effectively combine technology and growth planning. The proposed learning intervention aims to expose HE students to complex problems the solution to which requires the integration of interdisciplinary knowledge in engineering and economics in a manner that emulates real world problem-solving processes in the industry and society. Equally importantly, the project aims to build high order thinking skills such as non-routine problem-solving, communication, independent learning capacity, innovative thinking, evaluation of information stemming from diverse sources, ability to integrate diverse knowledge, ability to present solutions, and more.

HERA explores problem and project-based digitally-enabled educational design for re-engineering HE towards building young adults that have the potential to be innovators. This is pursued through active, gamified learning that challenges learners to collaborate, think entrepreneurially, and weave diverse knowledge towards introducing solutions to non-trivial problems inspired by 21st century needs. Digitally enabling the problem-solving process may effectively increase class communication, knowledge exchange, peer learning, and collective skill building, contributing to the development of desirable transversal skills. Gamifying the problem-solving process promotes active student engagement in learning through a sense of mission, a sense of affiliation, healthy competition, rewards, and social recognition by peers among other mechanisms. Furthermore, HERA aims to empower educators to integrate the proposed active, game-based learn interventions into classrooms through good practice guidelines thus enriching existing practices and promoting career satisfaction. The proposed digitally enabled active learning framework is designed, implemented, and validated with contribution by HE organizations in Greece, Portugal, Spain, Estonia, and Denmark.

2 ANALYSIS OF THE DEPLOYMENT OF ICT-BASED SOLUTIONS IN ENGINEERING AND ECONOMICS HE EDUCATION

2.1 Background

There is a growing interest in Europe about the development of soft skills in higher education. Educational institutions are required to produce highly skilled graduates who are capable of responding to the ever changing and complex needs of the contemporary workplace environment. Therefore, to a greater or lesser extent, education curricula across Europe has been introducing soft-skills at all levels during the last two decades.

At present, the way in which soft skills are being taught and assessed in different countries and educational institutions is very diverse [1]. This situation cannot be considered as strange in the view of other existing diversities around soft skills. The first diversity can be observed in the different ways of naming “soft skills”: key competences, transversal competencies, general competencies, essential competences, etc. In addition, the different concepts involved about what is considered as a soft-skill is also varying. Large lists of skills can be found everywhere and new soft skills are continuously being proposed. Additionally, it is also possible to find many variations in the manner of classifying and clustering soft skills into taxonomies.

Generally, soft skills are included through the whole curriculum, but not in any specific subject or module. Curricula usually show several subjects where some soft-skills are trained and assessed, despite in many cases there is not a clear definition about how it is done. A minority of institutions have formal practices such as curricular units integrated in the official curricula [2]. The E-QUA (Erasmus Quality Hosting Framework) project, whose purpose is to map the various models of mobility in Europe (http://www.equa-project.eu/), gives a description of the situation regarding soft-skills on European universities. From the analysis, only eight out of twenty-eight universities offer a soft skills development programme and the developed skills are mostly operative skills, intellectual/practical/relational/managerial skills, personal skills and thought skills.

Research on soft skills teaching methods and tools development shows the following activities are widely used by engineering departments to support their development [3]:

- Capstone projects (thesis).
- Specific course implementation (e.g. Design Thinking, Experiment Design).
- Clinical pairing, internship, industrial training program.
- Competitions.
- Incorporation of soft skills training and practicing in all courses.
- Partnership for interpersonal professional development with training schools outside the university.
- Multiple-solution problems with problem-based learning that require system-wide engagement.

Nowadays, ICT-based tools are usually involved in the teaching of university courses, many times as a kind of blended learning approach. Collaboration, communication, and productivity tools are usually used to enrich learning experiences. With their various functionalities, digital tools offer more opportunities for teachers who can engage their students in interactions that are not available in a traditional classroom setting. They can be used to stimulate learning by doing and help students develop their competences. Next, we explore different kinds of ICT-based solutions that have been described to support teaching and training of soft skills.

2.2 Serious Games

The use of games to support the instruction of soft skills has been recognized by existing literature [4]. The use of games in training offers benefits over traditional education in the sense that it is a practical learning approach that builds knowledge that can be applied in practice. Under the assumption that practice precedes theory, the learning process is developed with the objective of solving situational problems, whose emergence is controlled by the game. On the contrary, traditional learning systems promote educational approaches that are focused on the trainer as the center agent of learning and less as a facilitator of knowledge and mentor in the learning experience of the student.

Serious games enhance soft skills development by facing different situations, challenges, and problems and therefore make it possible to put learning into practice. A recent published book [5] describes examples of educational games for soft skills training in digital environments. Most of the examples involve some kind of role-playing that can be considered as a simulation.

It is possible to find some examples of serious games in the scientific literature to support the training of soft skills. Sousa & Rocha [6] present the results of a study about Game-based Learning (GBL) to improve soft skills. GBL is a concept that is structured around a learning process that uses as the main pedagogical tool a specific game which helps develop skills and competences. This project included a course around a social game, SimCity Social, with the objective of developing project management soft skills. The main goal was to use a game that could provide diverse contexts for the learners in order to develop leadership, time management, and team management skills. Particularly, the authors describe the Hotel Management Game. There are four player roles in this game i.e. the Marketing Player, the Front Office Player, the Housekeeping Player and the Food and Beverage Player. Then, process flow diagram from a simulation technique is implemented for each of the player role that involves in the architecture. The simulation embedded in the game ensures the representation of realistic scenarios which occur in hotel management. Therefore, the key processes of a certain activity are coded in the process flow diagram.

2.3 Gamification

A common complaint of many teachers and trainers refers to the fact that soft skills are very difficult to be taught in an online course. To tackle this situation, gamification has been proposed. This approach involves the creation of a special (online) environment, mixing content and interactions together with game elements that create an positive environment for learning in an easy and fun way. Using gamification in online courses involves game and play elements and/or game-design techniques, such as score and points, challenges, progress monitors, and leader boards. Online learning platforms, such as Moodle®, include plugins with numerous gamification elements that can be used to gamify online courses.

Dochie et al. [7] describes an online course focused on developing soft skills combining gamification and scenario-based learning: Skill Generator Assessment Game. The proposal includes both traditional online learning based on course presentations and a game-like assessment that aims to create game-like experiences for learners. The assessment uses interactive content and scenario-based learning. Gamification elements, such as points and leader boards, are also included.

2.4 Active learning

Active learning is a student-centered learning approach through which learners build knowledge by means that go beyond traditional lectures. In active learning, learners build knowledge by doing. Active learning is a very flexible approach that may involve broad and diverse activities, such as role playing, writing, presenting, visiting sites of interest, solving problems, or working on projects. Universities gradually adopt active learning as a result of the benefits that the approach offers in terms of knowledge retention and knowledge transferability from the academic environment to the world of work. Active learning prepares students to act as responsible citizens and professionals to address industry and societal challenges. A research [8] has shown that this approach supports the development of competencies such as teamwork, critical thinking, and analysis. In addition, students' performance and effectiveness are improved. Active learning is particularly useful in engineering and economics principles. It allows learners to build and use knowledge in a manner that simulates real world practices that prepare them to transition to the world of work as effective professionals.

3 HERA METHODOLOGY AND INNOVATION

3.1 Methodology

HERA aims to develop HE student skills aligned with the needs of the world of work and society. The challenges faced by society in the 21st century require solutions that weave skills and knowledge from diverse subject areas and sectors towards introducing integrated, viable, and sustainable solutions to pressing issues. The solutions to many of these challenges are rooted in a combination of engineering and economics principles. Examples include providing wide access to knowledge and information, including affordable solutions to on-line educational services through wireless networks and inexpensive devices for remote areas, providing access to affordable and environmentally friendly energy through renewable resources and suitable distribution networks for remote areas, reducing pollution through solutions that lean heavily on renewable energy resources, and others. The need to introduce solutions to such emerging societal challenges has further changed the way industry works, pointing to the need for integrated, potentially cross-sectoral approaches to solutions of complex problems. In this light, HE must be re-thought and re-engineered in order to build the skills that young engineers and economists will need to become leaders in their field and in society towards addressing 21st century challenges. HE needs to develop not only core knowledge but also soft skills that include high order thinking, communication skills, ability to evaluate information, ability to solve problems by integrating diverse knowledge, ability to learn independently, ability to present ideas to peers and to the public, and more. HERA addresses exactly this need, introducing active learning interventions that help build the foundations of engineering and economics knowledge as well as soft critical, analytical, innovative mindsets and the capacity of young scientists to work across borders and fields.

HERA aims to achieve the above objectives by introducing an active, experiential learning approach that exposes students to the industrial business processes for the 21st century. Research shows [9] that that active learning increases the performance of students in science, engineering, and mathematics. HERA aims to design an active learning framework for HE classrooms that increases the active participation of students in learning and their engagement in problem solving activities that promote critical and entrepreneurial minds. Furthermore, the HERA framework exposes students to project-based approaches deployed in industry, thus preparing them for what they will be exposed as young professionals upon graduation.

The HERA active learning methodology is applied and validated in practice through the development of digital learning solutions or in other words, simulations of the way the real-world works, thus digitally enabling HE education multidisciplinary offerings that com through open software designed for free use by all interested parties. The tools act as good practice examples of how HE education can be further linked to the needs of the world of work through virtual educational services that help students become immersed into industrial business processes thus building their capacity to become effective problem solvers for addressing societal needs.

HERA aims to design and implement digital learning services that promote problem-based learning in higher education. The proposed services simulate real world practices that combine engineering and economics principles through serious games that challenge students to solve complex problems the solutions to which require interdisciplinary knowledge. The proposed services enrich classroom collaboration and interaction and encourage learners to work in teams that collectively possess the knowledge necessary for solving complex 21st century challenges.

HERA aims to further support instructors and build their capacity to integrate emerging digital technology and problem-based learning design into existing educational practices. This is pursued through the development of instructional support content and good practice guidelines that help educators enrich their teaching skills.

3.2 Innovation

The innovation of the proposed learning intervention is a combination of a) the high level objectives of re-engineering HE in the multidisciplinary of engineering and economics for building innovation related skills needed for the 21st century and b) the proposed active, gamified digitally-enabled learning solution that promotes the development of field knowledge as well as problem-solving capacity by emulating the real world thus facilitating the transfer of student knowledge from the academic environment to professional activities upon graduation.

In relation to the re-engineering of HE offerings, the work studies the current HE practices in relation to emerging 21st century industry and societal needs and propose educational interventions that facilitate the alignment of skills built through formal and informal activities to business processes for addressing complex societal challenges the solution to which stems from exploiting knowledge, technology, and emerging business processes in engineering and economics. The nature of 21st challenges is complex and the design of solutions requires not only the weaving of knowledge from diverse subjects and themes in a specific discipline but potentially interdisciplinary knowledge that spans wide professional activities. This fact highlights the need for education that builds the problem solving capacity of young scientists and professionals in a manner that allows them to effectively work in teams and large groups, often cross-sectoral and cross-border, to evaluate information from diverse resources, to think entrepreneurially, to be open minded, to effectively evaluate and present solutions to peers, and more.

The above are all characteristics of an effective problem solver and critical thinker and need to be reinforced in today's young generation. HERA aims to address these emerging educational needs of our society through a methodological learning framework that is based on active learning approaches proven effective in engineering and economics education. Active learning addresses well HE objectives of building knowledge that students can deploy in the real world by exposing students to educational scenarios inspired by industry and society. Active learning is combined with game-based educational interventions that that further reinforce problem solving capacity [10] through the development of stronger social networks, a sense of mission for emerging challenges, promotion of productivity through the engagement with activities that are meaningful to the player, and internal motivation for tackling the world’s large issues.

The HERA methodological framework is reinforced through technical solutions based on ICT that facilitates the underlying active learning design. Specifically, the proposed digitally enabled solution revolves around a gamified learning platform that challenges learners to go through problem solving steps such as identifying the objective of a problem even when this is not clear, understanding interests, brain storming, evaluating solutions, prioritizing of tasks, and monitoring. The gamified learning platform is highly interactive and introduces motivation and engagement related elements such as rewards, social recognition, missions, and collaboration all of which are elements that can positively reinforce problem solving activities. HERA exploits the advantages of gaming approaches in learning that have been shown to contribute to the development of "soft" skills when other solutions fail [11]. Game-based learning provides students with the opportunity to engage in problem-solving activities that they would otherwise not be exposed to as a result of lack of infrastructure or high educational costs.

4 EARLY DESIGN

A serious game is being designed and developed with the objective of exposing HE students to active and problem-based learning scenarios that simulate real world industry practices. The scenarios give students a mission and describe an open-ended, non-trivial objective in the context of a city building simulation observing time and budget constraints. The setup of the application challenges students to integrate knowledge from diverse subjects to address the overall goal. At the same time students are challenged to collaborate in teams and to build project management skills.

Learning scenarios are being selected by engaging students in order to ensure that the final outcome will address their interests and needs. Some of the scenarios under consideration include:

- Design and implement festive light decorations for a city.
- Design fire protection strategies for a city.
- Design a fast data network for a city.
- Deliver energy to a city through green practices.
- Design a fault tolerant electricity network for a city.
- Design earthquake protection for a city.
- Design flooding protection for a city.
- Design fire protection for a city.
- Design an energy and water provision service for an island.
- Make adjustments to public buildings so that they are energy efficient.

These scenarios were suggested by students enrolled in the Technology for Education course of the Department of Electrical and Computer Engineering of the University of Thessaly in Greece. A collection of 7-8 scenarios will be developed by project completion taking into account suggestions from students in other countries, and specifically Portugal, Spain, Estonia, and Denmark.

The first scenario on the design of festive light decorations for a city is currently in full development. The development of a complete scenario will help address all gamification aspects of the proposed learning application and provide the basis for the development of additional scenarios. Some early images of the light decorations scenario appear below. The image on the left demonstrates the entrance screen to the game, through which learners will be able to select a challenge to follow. The image on the right shows an early version of the light decorations, demonstrating how a city is being lit through a variety of options available to the game user.

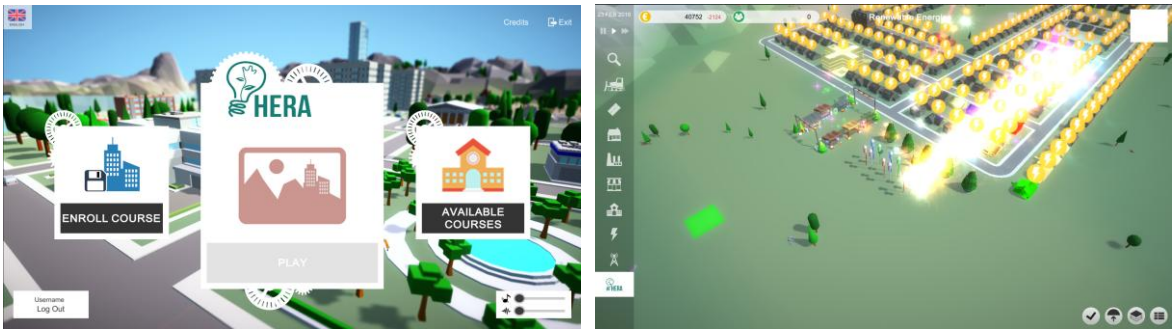

Figure 1. Early screen shots of educational scenarios for active learning in engineering and economics education.

The learning game is being designed to be a multi-player application and to be played in teams. Each team member adopts a specific role and has a different view of the game. Each student aims at different objectives, which may be antagonistic to those of other team members. For example, all team members may have to work within a common budget. However, all students as a team must fulfill the overall goal of the game.

Students receive feedback on their progress in diverse ways. The user interface provides information on the resources that students can use to achieve their goal, such as different types of building lighting and street lighting. Each resource has a cost; students have an overview of the remaining budget at the top left of the screen. Furthermore, students need to introduce electricity production facilities that can support the energy demands of the scenario and take into account failures in the system. Students are challenged to experiment with resources to achieve the desired results. The scenario is open ended. Different teams will achieve different solutions, setting the stage for classroom discussion on achieving optimal results.

5 CONCLUSION

This article presented a game-based, active learning approach that helps enrich engineering and economics HE practices. The work deploys active learning approaches that simulate how young

scientists in engineering and economics will be challenged to introduce solutions to real-world problems in a fast changing 21st century with pressing global issues and rapidly evolving technology and business processes. A serious game is under development that challenges learners to tackle real world problems the solution to which requires the combination of knowledge from diverse fields in a manner that simulates problem solving practices in industry. A number of scenarios are currently being integrated into the game that demonstrates the wide applicability of problem solving methodologies in engineering and economics. The game will be validated in Greece, Portugal, Estonia, Denmark, and Spain in the fall of 2020.

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