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Intellectual Output 1: Educational requirements and problem-based learning methodologies for re-engineering higher education to address emerging industry needs

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Authors:

Carlos Vaz de Carvalho, Virtual Campus

Hariklia Tsalapatas, University of Thessaly

Olivier Heidmann, University of Thessaly

Christina Taka, University of Thessaly

Nadia Vlahoutsou, University of Thessaly

Costas Katsimentes, University of Thessaly

Sotiris Evaggelou, University of Thessaly

Lene Sorensen, Aalborg University

Triinu Jesmin, Tallinn University

Jaanus Terasmaa, Tallinn University

Manuel Caeiro Rodriguez, University of Vigo

Mario Manso, University of Vigo

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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 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 higher education 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.

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This work presents the HERA learning intervention that applies active learning design to build problem-solving skills among higher education students in engineering and economics. HERA addresses the interdisciplinary needs of higher education 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 higher education 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-based digitally enabled educational design for re-engineering higher education 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

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contribution by higher education organizations in Greece, Portugal, Spain, Estonia, and Denmark.

This output constitutes the theoretical framework of the HERA project. It aims to:

- Establish a map of stakeholders that may gain directly or indirectly from the proposed objectives of the HERA project, that is, the re-engineering of multidisciplinary engineering and economics practices in higher education to better integrate active, problem based, social learning approaches for building non-routine problem-solving skills required for addressing the complex, cross-sectoral issues that face society in the 21st century. The map describes the groups as well as the interdependencies between them
- Establish the current situation in multidisciplinary engineering and economics offerings higher education on building skills required for 21st century students
- Review other research and development work in terms of promoting emerging active, problem-based learning approaches in engineering and economics
- Perform a needs analysis of direct stakeholders, namely higher education students and educators in terms of building skills required by global industry in multidisciplinary engineering and economics practices
- Introduce an active, problem-based learning educational framework for building non-routine problem-solving skills

This report constitutes a report on the outcomes of the tasks described in the project proposal for intellectual output 1:

Section 2 describes the outcomes of Task 1.1, which focuses on the establishment of a map of stakeholders that benefit directly or indirectly from project objectives, activities, and outcomes.

Section 3 describes the outcomes of Task 1.2, which focuses on the identification of desirable skills for young scientists in the 21st century.

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Section 4 describes key concepts on problem-based learning and related methodological educational design

Section 5 describes the outcomes of Task 1.3, which focuses on an analysis of the current situation in engineering and economics higher education.

Section 6 describes the outcomes of Task 1.5, which focuses on an analysis of the deployment of technology for the support of innovation-focused education.

Section 7 describes the outcomes of Task 1.4, which constitutes a questionnaire-based study that engages students towards identifying their desires and needs in terms of innovation-focused education.

Section 8 describes the outcomes of Task 1.6, which is the analysis of the learning needs of students.

Section 9 describes the outcomes of Task 1.7, which focuses on the analysis of the skill building needs of educators.

Section 10 describes the proposed HERA active, problem, and game-based learning solutions that aim to complement existing instructional practices in innovation-focused education.

This report constitutes the result of collaborative work among project partners, in which the strengths and expertise of each has been exploited for leading the analysis in the diverse aspects of establishing a methodological learning framework that drives the design of the HERA learning game for innovation-related skill and competence development.

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2. Defining the target group and stakeholders

The HERA project aims to introduce a user centered approach for building the problem-solving skills that industry and society needs in the 21st century. This section introduces an analysis of the stakeholders that stand to gain directly and indirectly from effective learning in higher education. It discusses the interests and needs of each group and addresses how problem-based learning can benefit participants and contribute to individual objectives and well-being.

2.1 Direct stakeholders

Direct stakeholders are individuals that are expected to directly benefit from problem-based learning (Shmeer, 2018). These individuals will use actively and hands-on the HERA problem-based learning methodologies and digital tools. They are:

2.1.1 Higher education students

Higher education students are the problem-solvers of tomorrow. Today's young generation will be faced with significant challenges, such as mitigating climate change, quality education for all, health for all, eradicating poverty, equality, responsible management of natural resources, and more (United Nations Sustainability Goals, 2021). In addition, higher education students with combined engineering and economics knowledge will be called to exploit rapidly evolving technological innovations for introducing solutions that address industry and societal challenges and enrich quality of life. In fact, growth in the coming years is expected to come from innovation related sectors, in the heart of which are engineering and economics. To effectively prepare for their professional and civic future roles, students need to build both foundational knowledge in their area of study as well as soft skills in demand by industry and society, such as team building, collaboration, conflict management,

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project management, analytical thinking, working within a specific budget and time schedule, learning to learn, and more.

Solutions to the real-world problems of today cannot be introduced by a single individual, as no-one possesses all the required knowledge for addressing complex challenges. In real-life, problems are solved by interdisciplinary teams in which each team member brings complementary expertise and competences. For example, to introduce quality of life services in a city, an implementation team may need engineers, urban planners, economists, cultural coordinators, health specialists, equality specialist, and a lot more. In addition, in an effective team, team members offer strengths in soft skills in areas such as coordination, ideation, evaluation of diverse ideas for selecting the most appropriate for a given situation, implementation, polishing of final products and services, and more (Belbin, 2021).

Students can benefit from educational design that promotes not only the development of basic knowledge and soft skills, but also their transferability from the academic environment to the world of work and across sectors (European Commission, Transferability of Knowledge across Economic Sectors, 2013). Knowledge transferability is one of the key challenges in higher education, and the HERA project aims to achieve just that: promote the development of foundational knowledge as well as problem-solving capacity among higher education students by exposing them to complex, open problems the solution to which requires the integration of knowledge from diverse subjects and collaboration of teams with complementary, multidisciplinary competences in a manner that simulates real world industry practices.

2.1.2 Higher education instructors

Higher education instructors are the individuals that foster the development of knowledge and skills among students, the professionals of tomorrow. They are impacted by fast-moving change in society (European Commission, Modernization of Higher Education in Europe, Academic Staff, 2017). These individuals have high qualifications, such as doctoral degrees,

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and in-depth initial training. The rapid evolution of technology, in combination with emerging pedagogies, leads to the need for the continuous updating of instructional practices throughout their career to support the development of knowledge and skills among students in a manner that allows transferability to the real-world. Building the skills of instructors to foster competence-based learning is identified as a key objective in education and training in the European Commission (European Commission, Key Competences and Basic Skills, 2018). In addition, the importance of introducing a variety of learning approaches and contexts is highlighted in the same communication.

Higher education instructors can benefit from upgrading their skills towards designing and introducing to the classroom emerging problem-based learning activities that help build 21st century skills. Emerging pedagogical design leads to the evolution of the role of educators (Delisle, 1997). The educator does not transfer information through lectures, as happens in traditional classrooms. Rather, the educator's role has shifted. He is a facilitator and guide who comments on student activity and answers questions that guide learning participants to the right direction, encouraging them to be more independent and to assess and evaluate their work.

On the other hand, in the context of bringing education to the digital age, digital applications and tools can help educators enrich classroom interaction when integrated into broader blended learning design that combines instruction and hands-on practice. Educators today teach students that are digital natives, meaning they effortlessly use technology in all aspects of their lives. In this context, there is a broad recognition of the need to bring education to the digital age (European Commission, Digital Education Action Plan, 2021).

Educators can benefit from open educational digital applications, developed specifically for learning. They can further benefit from tools that allow them not only to use available digital material but also to create their own for addressing the individual needs of their students in specific educational contexts. Thus, educators will benefit from the HERA digital learning intervention for problem-based learning, the educational scenarios that will be developed

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that can provide inspiration for developing additional related activities for their students, the instructor support content that will facilitate the integration of problem-based learning into instructional practices, and the good practice guidelines on maximizing the impact of problem-based learning.

2.1.3 Higher education institutions

Higher education institutions need to modernize educational practices and offerings with the objective of increasing participation and developing the skills and knowledge that today's knowledge-based economy and society needs. They further need to ensure the employability of students, facilitating their transition to the labor market. And they need to demonstrate the links between education and real life, which can contribute to student retention and higher completion rates reaching the target of over 40% of Europeans completing a higher education degree (European Commission, Modernization of Higher Education in Europe, Access, Retention and Employability, 2014).

Building the skills that industry and society today need may be greatly facilitated through the integration of emerging pedagogies and supporting digital technology for making education relevant and updating learning practices. Higher education institutions can further benefit from educational initiatives promote stronger links between academia and industry towards developing knowledge that helps address emerging business and societal needs. Outcomes of the HERA project will be integrated into the organizational strategies of institutions engaged in the project. Outcomes will further be promoted to higher education institutions beyond the consortium through dissemination and uptake activities.

2.2 Indirect stakeholders

Indirect stakeholders are individuals and groups that, while not using hands-on and directly the project outcomes, are still expected to benefit from the proposed digital, problem-based learning intervention. These are:

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2.2.1 Higher education administrative personnel

Higher education administrative staff is involved in educational organization by supporting the educational process through numerous activities such as organizing and supporting classes and examinations, organizing surveys with educators and students, supporting dissemination of educational outcomes, promoting organizational activities to the community, establishing links with external bodies, and more. The engagement of higher education institutions in a wealth of innovative activities nurtures administrative personnel and promotes career satisfaction through diversified missions that encourage them to proactively engage with the wider society (Baltaru & Soysal, 2018). While administrators do not directly apply problem-based learning they do support the educational process and thus can benefit from understanding the focus of related pedagogies, the day-to-day implementation good practices, and the positive impact of innovative learning design to the educational community for achieving educational objectives.

2.2.2 Industry

Industry partners need young professionals that have the skills and knowledge needed for pursuing emerging business opportunities and projects. There is a shortage of engineers in Europe, as well as shortage of professionals in the information technology sector (CEDEFOP, Skills Shortages in Europe, 2016). This shortage is significant as innovation related sectors, including engineering and information technology, are expected to drive economic growth in the coming years and decades, helping create jobs in other sectors as well.

Emerging pedagogical design, such as problem-based learning offers the potential of building the competences and knowledge that industry partners need in the 21st century, simulating the way knowledge is deployed in real-world business practices and preparing students to become effective professionals upon graduation. Industry partners can also benefit from their collaboration with educational organizations for promoting modern curricula that

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address the skills that industry and society need in the 21st century, including theoretical knowledge, practical skills, and soft skills.

2.2.3 Digital learning management platform providers

Information technology providers develop digital platforms, applications, and services that support the educational process. These may include stand-alone digital content, learning games, digital content management systems, digital learning management systems, massively open on-line courses (MOOCs, Wikipedia 2021) that help reach large groups of students or build specialized knowledge, and more. Information technology providers that work on educational solutions can benefit from a thorough understanding of the needs of higher education institutions, educators, and students towards building relevant and up-to-date skills that industry and society need. This understanding will help them tailor their products and services to market needs and to better position them against their competition. They can also benefit from insight built through the design, development, and evaluation of information technology supported educational initiatives and the feedback provided by direct stakeholders, namely educators and students, on their relevance, usability, effectiveness, and overall enrichment of learning processes. Educational information technology providers will have access to the methodological learning design of HERA as well as the results of validation and piloting activities and resulting good practices.

2.2.4 Lobby and voluntary organizations

These are organizations that focus on specific challenges such as sustainability or humanitarian issues and organize campaigns for their support through crowd sourcing and awareness development. These organizations will have an appreciation of soft 21st century skills including collaboration, communication, team building, leadership, problem solving, actively engaging in civics, and more that are promoted by the HERA project.

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2.2.5 Local community stakeholders relating to the HERA problem-based learning scenarios

The HERA project aims to introduce problem-based learning through an educational approach that exposes students to scenarios inspired by real life, the solution to which requires the integration of knowledge and the deployment of soft skills. Local shops, electricity companies, environmental organizations, and others may represent stakeholders in the educational scenarios and learning games the project will develop. The proposed learning intervention will promote a better understanding by students of the challenges faced by these stakeholders in their everyday operations through their engagement in the proposed virtual learning environment as well as face-to-face interaction outside the university. Students will develop a better appreciation of business challenges and community stakeholders will benefit from the better preparedness of students to address real world problems actively and effectively.

2.2.6 The general public

The proposed learning intervention on problem-solving skill development will be based on real-life scenarios that address real-world issues. While these educational scenarios target mainly higher education students, they are of interest to all. They may benefit the general public by building a better general understanding on community issues, such as traffic, shopping hours, environmental aspects, access to services, governmental support, and more. Furthermore, the project can develop a better understanding of the human aspect of everyday problems among policy makers, contributing to the better acknowledgement and more effective addressing of community challenges. Furthermore, the general public will benefit from a young generation that is better equipped to engage and introduce solutions to local, regional, and global 21st century challenges through enriched problem solving and soft skills.

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2.2.7 Policy makers at the European and national level

The proposed active learning intervention focuses on soft skills that foster enriched general understanding of complex societal problems. Currently, there can be a challenge for policy makers at all levels to attract young people to the policy field. HERA raises awareness of the need for problem solving and soft skills, which may benefit policy makers at all levels in that more individuals may be interested in working with the type of complex political problems politicians work with.

The identified stakeholder groups have different impact and interest in active learning. An overview of their interests and influence can be found in the map presented in the following figure.

Students and educators have both high interest and high influence on the input and the outcomes of the HERA project, which is a result of the benefits they receive through their engagement in innovative learning design.

Administrative personnel, higher education institutions, industry, and policy makers have been placed in the high influence and low interest group. Administrative personnel is placed in this category since they do not necessarily care about the details of project results but have an influence on institutional educational practices, including active learning. Policy makers have the power to influence the adoption of wide adoption of project outcomes and therefore have a high influence. Industry has influence with respect to playing key roles in identifying educational needs but not necessarily a keen interest in details of the project implementation.

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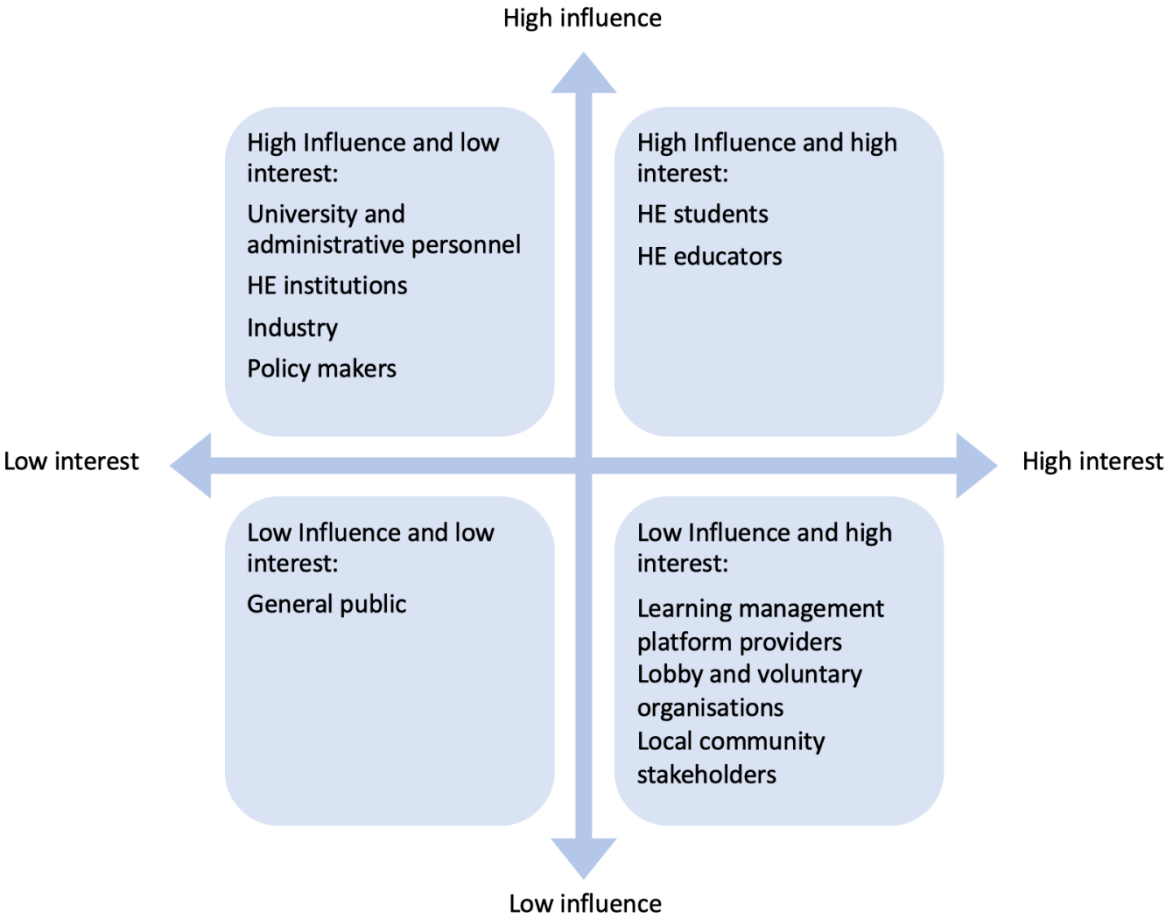

Figure 1. HERA stakeholders, organized by interest level and influence on HERA active learning initiatives.

The general public has been placed in the low interest and low influence category. The general public may have interest and influence on the project results and stands to benefit from HERA activities but is not actively engaged in the project beyond dissemination and uptake activities.

The low influence and high interest categories include the learning management platform providers, lobby and voluntary organizations, and the local community stakeholders. The learning management platform providers may be interested in projects results for their own benefit and for informing their activities on the design of educational IT services but do not have a direct influence on the project implementation. Lobby and voluntary organizations as

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well as the local community stakeholders have an interest in skills developed by the project; they will be indirect beneficiaries of the project because of the increased awareness of students in their work and the fostering of a young generation that is civically active. However, these organizations do not have much influence on the project implementation.

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3. Identification of desirable skills for young scientists in engineering and economics

The previous section developed an understanding on stakeholder groups that will benefit, directly or indirectly, but the HERA problem-based learning intervention that helps build 21st century skills and competences among students in engineering and economics. A further analysis of these skills that are desirable for effectively working in the engineering and economics sectors in the 21st century is presented below. The purpose of the analysis is to establish the skills that students need for their own benefit and the benefit of their communities, which will be the basis for the design of the HERA problem-based learning intervention.

This analysis considers the fact that 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 of 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, higher education must be re-

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thought and re-engineered 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.

The process for identifying desirable skills started with an analysis of the personal characteristics needed for engineers today through a review of existing frameworks: 21st century skills (Dede, 2010), skills you need (Skillsyouneed, 2020), P21 framework (P21 Framework, 200; Doyle, 2020), cognitive skills (Reed, 2000). The process led to the selection of 44 general characteristics, of which 18 were considered fundamental:

In the HERA proposal, the following skills were identified:

- Formal, basic knowledge in engineering and economics
- Integration of knowledge from diverse thematic areas
- Collaboration, sometimes in multidisciplinary teams
- Open mindedness
- High level thinking
- Critical, analytical, and innovative thinking
- Independent and autonomous learning
- Problem solving
- Ability to prioritize
- Evaluation of information particularly when coming from diverse sources
- Following systemic design processes
- Implementing and validating solutions from the perspective of the end users
- Analyzing factors that contribute to an unwanted situation
- Designing and evaluating alternative interventions towards solving a problem
- Implementing and assessing the effectiveness of a solution
- Transferring knowledge to the real world
- Working with limited resources
- Effective communication skills

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Many of the above can be described as soft skills, for which there is growing interest European higher education. Educational institutions are challenged to develop highly skilled graduates who are able of effectively responding to the evolving and complex needs of the contemporary workplace environment. Therefore, to a greater or lesser extent, educational curricula across Europe have been introducing soft skills at all levels during the past two decades.

Today, the way in which soft skills are being taught and assessed in different countries and educational institutions is very diverse (Cinque, 2016). 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, concepts involved on what is considered as a soft skill are also varying. Large lists of skills can be found everywhere (The Balance Careers, 2019) 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.

Soft skills are developed throughout curricula but not in a specific subject or module. Curricula usually include several subjects in which some soft skills are developed and assessed, although in many cases the learning method is not clearly defined. A minority of institutions have formal practices such as curricular units integrated in the official curricula (Bastos et. al, 2019). The E-QUA (Erasmus Quality Hosting Framework) project, whose purpose is to map the various models of mobility in Europe (E-QUA project, 2020), provides an analysis of the current situation regarding soft-skills on European universities. The analysis concludes that only 8 out of 28 universities offer a soft skills development program. The developed skills are mostly operative skills, intellectual, practical, relational, managerial, personal skills, and thinking skills.

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The following table presents a further analysis of desirable soft skills in engineering and economics and presents a justification for their importance for students in engineering and economics.

Skill	Description and justification of need
Digital literacy	**Description:** Ability to find, evaluate, and clearly present information through writing and other media on various digital platforms. **Justification of need:** Digital skills are necessary in all economic sectors today and are basic competences along with STEM and language skills. Digital skills are required for performing everyday activities, using specialized software, communicating, presenting, and more.
Information and media literacy	**Description:** Ability to show and make informed judgments as users of information and media as well as to become skillful creators and producers of information and media messages. **Justification of need:** Students and professionals use media and the internet as a source of information. The ability to evaluate information from diverse sources in significant in synthesizing solutions. Furthermore, as content creators,

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	students need to understand concepts related to media presence and safety on the internet (CEDEFOP, Researchers and Engineers: Skills, Opportunities, and Challenges, 2016).
Health and wellness literacy	**Description:** Ability to obtain, process, and understand basic health information and services needed to make appropriate health decisions. **Justification of need:** Developing solutions to business and societal challenges requires the analysis of problems from diverse viewpoints, such as technical, societal, economic, and health. Wellness literacy is a necessary skill for effective problem analysis and solution design.
Formal, basic knowledge in engineering	**Description:** Knowledge and ability to apply the fundamental concepts of STEM required for following an engineering career. **Justification of need:** Formal engineering knowledge is key to synthesizing solutions to today's challenges. This is the knowledge that is developed through formal educational higher education curricula.
Economic and financial literacy, entrepreneurialism	**Description:** Knowledge and ability to apply the fundamental concepts

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	of math, economics, business, and more required to follow an economics career. **Justification of need:** Theoretical economics knowledge is key for developing a successful career in the field. This knowledge is developed by formal higher education economics curricula.
Ethics	**Description:** Ability to understand, apply, and assess the moral principles that govern a person's behavior in everyday life and in professional contexts. **Justification of need:** Ethics is an important dimension when analyzing a problem. Ethics need to be taken into consideration when designing human-centered solutions that benefit individuals and communities.
Global Awareness	**Description:** Ability to understand, respect, and work well with people from diverse cultures. **Justification of need:** Modern challenges need to be addressed with both a local and global perspective. Today's interconnected world requires solutions that work for all. In addition, today's business environment is multicultural. In this environment individuals need to work harmoniously with

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	peers from diverse cultural, educational, and economic backgrounds.
Independent and autonomous learning	**Description:** Ability to learn independently and autonomously. **Justification of need:** The ability to learn independently is one of the transversal competencies that individuals need to build in addition to formal knowledge. It is necessary for staying up to date with technological and business evolution in the span of a long career.
Willingness to learn	**Description:** Willingness to explore and build knowledge for continuous self-improvement. **Justification of need:** Knowledge development is a process that to a great extent is based on internal motivation. Willingness to learn drives students to explore new knowledge and to develop knowledge through experience. Willingness to learn is also important in problem-based learning methodologies, in which the responsibility for learning is to some degree transferred from the instructor to the student (CEDEFOP, Researchers and Engineers: Skills, Opportunities, and Challenges, 2016).
Evaluating information	**Description:**

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particularly when coming from diverse sources	Ability to analyze through critical thinking the reliability, validity, accuracy, timeliness, point of view, and bias of information sources. **Justification of need:** In today's connected world, information does not only stem from traditional resources, such as books. It may be discovered on the internet, in newspapers, on TV, in scientific articles, in social media, and a lot more. The ability to evaluate the validity of information stemming from diverse sources is important in today's environment in which technology allows broad access.
Integrating and synthesizing information	**Description:** Ability to compare, combine and generate a consistent message based on multiple, sometimes conflicting, sources of information. **Justification of need:** Synthesizing information that stems from diverse fields is the norm in problem-solving practices in the real world. Rarely in real-life is a problem solved by applying knowledge from a single field. Knowledge synthesis is a key transversal competency. It is highly relevant in engineering and economics.
Analytical and critical thinking	**Description:** Ability to break down complex information into

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	fundamental elements or units and to assess each of those. **Justification of need:** Analytical and critical thinking is a transversal competency that helps individuals solve problems independently of economic sector. Analytical and critical thinking is important both in education and in business. It is the basis of high order thinking activities in which students and professionals build new knowledge from old.
Innovative thinking	**Description:** Ability to look at problems or situations from a fresh perspective that could provide out-of-the-box solutions. **Justification of need:** Innovative thinking is a transversal learning capacity along with analytical and critical thinking. Innovative thinking is necessary for solving emerging 21st century complex challenges that require entrepreneurial mindsets to be addressed.
High-level thinking	**Description:** Ability to apply all the previous skills, namely analysis, evaluation, and synthesis or creation of new knowledge. **Justification:** High-level thinking involves the capacity of individuals to evaluate information, apply it, and create new knowledge

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	by synthesizing old. High order thinking skills, as opposed to traditional learning skills related to memorization of information, are desirable in industry. High-order thinking allows individuals to create solutions to real-world challenges through research, analysis, synthesis, collaboration, and integration of knowledge and information.
Open-mindedness	**Description:** Ability to be receptive to a wide variety of ideas, arguments, and information. **Justification:** Addressing pressing 21st century challenges requires exploration, collaboration, and experimentation with ideas that are often out-of-the-box. To introduce solutions that are human-centered and address real, as opposed to perceived, needs of stakeholder engineers and economists need to be open-minded, to listen to stakeholders, and to be open to ideas that range from conventional to innovative in order to create a pool of potential solutions that will be evaluated for selecting the most viable one.
Creativity	**Description:** Ability to perceive the environment, to find hidden patterns, to make connections between seemingly unrelated facts, and to generate solutions. Ability to turn

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	new and imaginative ideas into reality. **Justification:** Creativity, along with innovative, analytical, and critical thinking is a desirable transversal learning ability that allows individuals to introduce entrepreneurial solutions to complex real-world challenges. Creativity is a key ability in both engineering and economics, which are solution-oriented disciplines.
Flexibility and adaptability	**Description:** Ability to adapt to changing circumstances and environments and to adopt new ideas and concepts. **Justification:** Responding to change is important in an evolving technological and business environment. Agile design principles are inherent in engineering and aim at addressing evolving user requirements towards implementing solutions that address evolving needs. Change management processes are also important through protocols and practices that allow multidisciplinary teams to work together in an evolving environment.
Openness to criticism and feedback	**Description:** Ability to accept negative feedback without overly reacting emotionally.

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	Justification: Problem-solving often takes place in groups, in which members collaborate and exchange ideas. In this group environment it is important to both accept ideas without being overly critical, but to also be able to accept criticism without overly reacting.
Openness to ideas and thoughts	**Description:** Willingness to consider ideas and opinions that are new or different from own. **Justification:** Being open to the ideas of others is a sign of good collaboration skills and of the ability to listen and take in information from diverse sources. In the context of brainstorming towards finding a solution, being open to the ideas of others, even if these are different from an individual's personal perspective, is an important step towards creating a pool of potential solutions.
Initiative	**Description:** Ability to assess and initiate tasks independently. **Justification:** Leadership and the ability to initiate tasks and projects is as significant as being able to effectively collaborate in a group. Taking initiative and acting allows to put ideas into action and to implement solutions in both engineering

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	and economics.
Perseverance	**Description:** Ability to persist in a course of action, a purpose, a state, etc., despite difficulties, obstacles, or discouragement. **Justification:** Effective implementers have the capacity to not only introduce innovative ideas but to take the steps necessary for these ideas to turn into action. Innovation is important in solution design, but so is also implementation and hard work.
Self-direction	**Description:** Ability to make decisions and organize personal workload rather than being told what to do by others, such as managers, teachers, etc. **Justification:** Self-motivation and self-direction are important both among students and professionals not only in educational contexts but also in business. The ability to work independently is a transversal competency that is as significant as working effectively in a group. Self-motivation is a capacity that can lead an individual to seek progress in academic and professional contexts throughout their career (CEDEFOP, Researchers and Engineers: Skills, Opportunities, and Challenges, 2016).

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Self-discipline	**Description:** Ability to self-discipline, to set clear goals, and to work towards them every day. **Justification:** The ability to set clear goals and to see them through is another element of self-motivation and taking initiative. Along with perseverance, it enables individuals to set their own goals and to achieve them both individually and in groups (CEDEFOP, Researchers and Engineers: Skills, Opportunities, and Challenges, 2016).
Planning	**Description:** Ability to accurately identify and organize systems and resources, including time, required to complete tasks in an efficient way. **Justification:** Ability to organize and plan project implementation is significant in all engineering principles as well as in economics projects.
Ability to prioritize	**Description:** Ability to identify critical tasks and resources and to establish priorities systematically, differentiating between urgent, important, and unimportant processes. **Justification:**

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	Project management and implementation requires the identification of tasks and their prioritization based on requirements. Engineering principles, such as computer science, typically reply on project implementation through the breaking down of activities into smaller tasks and the prioritization of those based on the desirability and urgency of features. Prioritization of tasks allows incremental delivery, which in turn enables users to have access to basic product functionality early on in the implementation.
Assertiveness	**Description:** Ability to express thoughts, feelings, and beliefs in direct, honest, and appropriate ways. **Justification:** Being part of a team involves the expression of opinions and thoughts, which facilitate brainstorming and evaluation processes towards reaching a desirable result.
Being positive	**Description:** Ability to focus on elements that an individual can control. **Justification:** A positive outlook is important in complex projects for overcoming day-to-day development challenges and the pressure of project implementation in the long-term.
Sense of quality of work	**Description:**

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	Ability to analyze, judge, and critique a piece of work in a way that leads to an improved version of it. **Justification:** Quality assurance processes are part of every project implementation in engineering and economics. The ability to polish the result of a project in order to turn it into a final product that is ready for users is a key competency that is important to possess in a group.
Social interaction and empathy	**Description:** Ability to express feelings, ideas, and actions and to empathize with those of others. **Justification:** User-centered solution design requires empathy on behalf of design team members to understand the real, as opposed to perceived, needs of users and the actual parameters of a given problem. Empathy allows designers to understand the experience and feelings of users when exposed to a solution and to define accurate problem statements, which in turn lead to solutions that more effectively address user needs (Brown, 2019).
Active listener	**Description:** Ability to consciously focus on the speaker message. Ability to get a deep understanding of message conveyed. **Justification:**

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	Active listening is an ability that allows professionals to understand the viewpoints of their customers and their peers leading to effective collaboration and desirable results.
Collaboration and teamwork, sometimes in multidisciplinary teams	**Description:** Ability to productively work with others on common tasks to reach a common goal. **Justification:** Business and societal challenges are rarely addressed individually. Solutions to complex, 21st century challenges require the collaboration of multidisciplinary teams the members of which collectively possess the required knowledge. Being able to effectively collaborate in multidisciplinary groups, to openly listen to the viewpoints of others, and to integrate knowledge is an ability that contributes to the synthesis of solutions.
Leadership	**Description:** Ability to organize and motivate other people to reach a shared goal. **Justification:** Leadership is one of the transversal competences that are desirable for addressing complex problems independently of thematic area. Leadership itself is a combination of skills, including communication, motivation, positivity,

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	delegation, creativity, accepting and providing feedback, commitment, flexibility, and more.
Oral and written communication	**Description:** Ability to communicate thoughts clearly and concisely. Ability to communicate focus, energy, and passion. **Justification:** Oral and written communication allows an individual to convey ideas clearly and concisely, to create focus, and to motivate. They are both significant skills related to leadership.
Transferring knowledge to the real-world	**Description:** Ability to apply the acquired knowledge, skills, and competences in a different context or in a different way. **Justification:** One of the key challenges of higher education today is to build student knowledge and skills in a manner that allows their transferability to the real world. The transferability of new knowledge contributes to the bridging of the gap between skills built in academia and those required by industry. Problem-based learning fosters transferability through the development of knowledge in virtual or physical settings that simulate real world scenarios (European Commission, Transferability of Knowledge across Economic Sectors, 2013).

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Presentation skills	**Description:** Ability to deliver information clearly and effectively to a specific audience. **Justification:** Presentation skills are part of oral communication. They help an individual clearly bring a message across. Effective presentation skills are desirable independently of the area of work. Most individuals at some point will need to professionally present ideas in front of an audience. Good presentation skills are typically considered to be part of leadership skill sets.
Problem-solving	**Description:** Ability to understand a problem, use generic or ad-hoc methods in an orderly manner to find solutions, identify the most suitable ones, and evaluate them. **Justification:** Addressing the complex challenges of today requires high problem-solving skills. They are higher-order thinking skills that involve the most evolved function of the human brain. Addressing problems requires identifying an accurate problem statement, breaking down a problem into smaller parts, solving those, and synthesizing a solution from the results (CEDEFOP, Researchers and Engineers: Skills, Opportunities, and Challenges, 2016).

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Providing clarity to problems	**Description:** Ability to analyze a fuzzy problem and identify suitable objectives for solving that problem. **Justification:** The ability to clearly define a problem statement helps in synthesizing effective solutions. This includes identifying the problem objectives and understanding the parameters that affect the solution (Brown, 2019).
Analysis of the factors that contribute to an unwanted situation	**Description:** Ability to identify events, conditions or other aspects that created an immediate cause for an undesired situation. **Justification:** Project management requires systematic planning and the ability to organize actions for addressing diverse situations. For unwanted situations, the analysis of factors that could lead to undesirable states is significant for designing mitigation actions.
Following systemic design processes	**Description:** Ability to understand and apply methods that combine systems thinking and human-centered design to cope with complex design projects. **Justification:** Effective design of solutions requires knowledge of and

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	the ability to apply systematic thinking towards the implementation of effective actions that address real stakeholder needs.
Designing and evaluating alternative interventions towards solving a problem	**Description:** Ability to apply methods towards conceiving and evaluating potential solutions to a given problem. **Justification:** Designing alternative solutions is significant for several reasons. It allows teams to brainstorm, creating a pool of ideas towards the solution of a problem. It further allows teams to evaluate diverse implementation paths and to select a single or a limited number of solutions for prototyping and piloting, allowing the generation of feedback by stakeholders.
Implementing and assessing the effectiveness of a solution	**Description:** Ability to implement the solution and evaluate the achieved results from an efficiency point of view. **Justification:** The capacity to implement a solution is desirable in a team. It is the process of putting an idea to action and developing a final product, service, or intervention. Evaluation of the result is also significant for ensuring that it complies with user requirements and user needs.
Working with limited	**Description:**

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resources	Ability to design a strategic plan and implement decisions to respond to changing circumstances and demands that lead to scarcity of resources. **Justification:** Project management processes require implementation within limited resources, including financial budget, working with specific implementation teams, or others. The ability to navigate project implementation within limited resources is necessary for implementing a project in the real-world.
Time management	**Description:** Ability to plan and organize the division of time between specific activities. **Justification:** Time is another limited resource, as projects must be implemented within specific timeframes that are determined by external conditions including market and industry evolution. Time management skills include the ability to setup a timeline for project implementation, to identify implementation milestones, and to consider dependencies between implementation tasks.
Project management	**Description:** Ability to plan, procure, and execute a project with an efficient use of all the resources.

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	Justification: The ability to manage the overall project implementation process, which includes time management, financial management, allocation of resources, observation of dependencies, collaboration, and more is significant for all young professionals entering the world of work.

Table 1. Desirable skills in engineering and economics.

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4. Learning methodologies for building problem-solving and other soft skills

Some of the most common emerging learning approaches that are deployed in higher education and other contests for developing desirable problem-solving and other soft skills include:

Blended learning, an approach that integrates diverse educational methods, including traditional instruction, digital experimentation, site visits, and others that combined provide an active learning experience for students that more effectively addresses learning goals (Dziuban et al, 2018).

Flipped classroom, a methodology that aims at the higher engagement of students through blended, active learning approaches that allow teachers to address the diverse needs of students in terms of varying knowledge levels or learning difficulties and to personalize education. The teacher provides students with educational material before the lecture. The students review the material and use the classroom time to resolve questions, to work on practical exercises, or to engage in other activities that traditionally may be considered as homework. The teacher plays to the role of the mentor. Flipped classroom allows for more effective use of classroom time and encourages students to take responsibility for their learning (Nuri, 2016).

Problem-based learning, an approach in which students are challenged to solve a problem, often open-ended and non-trivial, using knowledge from diverse subjects in the curriculum thus simulating how knowledge is used in the real world (Delisle, 1997).

Cooperative learning, an approach that encourages students to work together towards achieving specific goals. This method is the opposite of broadly used educational approaches that are based on student competition. In cooperative learning the education sets up

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educational activities in a manner that requires student interaction and collaboration to be achieved. Students work in small groups for maximizing their benefits from the learning process as well as the benefits of others (Slavin, 2014).

Gamification, an approach that refers to the use of gaming elements in contexts other than entertainment. These include learning, training, crisis management, research, and more. Gamification elements may include rewards, recognition, a sense of mission, clear goals, a sense of affiliation, feedback, and more. In learning, well designed gamification may lead to the achievement of educational goals when gaming elements are integrated into practices in a manner that promotes the learning process (Welbers et. al, 2019).

Design thinking, an approach that allows the introduction of solutions to complex problems and the more accurate address of user needs through a process that enables the identification of real, as opposed to perceived needs. Design thinking involves a process of empathy for understanding the experiences and feeling of users when exposed to a particular solution, problem statement definition using user input and designer perspective, brainstorming, and prototyping of potential solutions in a manner that allows their use by affected individuals and the generation of feedback (Brown, 2019). It can be deployed for solving pressing challenges, to which a solution may not be evident at first sight.

Thinking-based learning, a methodology that aims to developer better thinkers; its goal is to lead to better lives outside of school. Thinking-based learning focuses on critical and creating thinking. It involves making decisions, solving problems, making predictions, evaluating information, and more. Thinking-based learning aims to transform classrooms so that the knowledge developed has a positive impact to students beyond the classroom (Swartz, 2008).

Competency-based learning, an approach that builds knowledge in a manner that allows learners to use it in real-world situations. It revolves around the development of educational activities that promote competences that can be measure against real-world standards. In

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this context, each competence is an individual learning outcome. Students work on a specific competency at a time. Competences are viewed as units that are part of broader learning objectives. Students must master each competence before focusing on the next (Clawson & Girardi, 2021).

Within these frameworks, the following learning activities are widely deployed: by engineering and economics departments to support their development (Cimatti, 2016):

- Capstone projects or theses
- Specific course implementation, e.g., design thinking, experiment design
- Clinical pairing, internships, and industrial training programs
- Competitions
- Incorporation of soft skills training and practicing in all courses
- Partnerships for interpersonal professional development with training schools outside the university
- Multiple-solution problems with problem-based learning that require system-wide engagement

The Modes project (Modes Project, 2020) identified different kinds of teaching strategies applied to soft skills. These can be divided into three groups:

- **Expository strategies**, that explain or interpret a comprehensive topic
- **Guided**, in which learners build knowledge through the guidance of the teacher and supporting content
- **Active**, in which learners build knowledge by doing and through experience in a manner that simulates everyday life

This division is demonstrated in the following table (Cinque, 2016).

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Expository	Guided	Active
Lecture	Discussion, debate	Brainstorming
Seminar	Workshop	Role play
Conference	Case study	Business game
Demonstration	Project work	Visits, journeys
	Simulation	Outdoor training
	Mentoring	Coaching

Table 2. Learning methodologies for developing soft skills.

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5. Current practices in engineering and economics higher education

With the stakeholders and desirable needs having been identified, this section focuses on the current strategies and practices related to how the higher education sector in engineering and economics addresses modern skill development requirements.

A good practice is an activity that has been demonstrated to produce desirable results and for this reason it is suggested as a model for others to apply. It is a process that has been validated and shown to produce good results. For this reason, it is made public so that a greater number of individuals can benefit from its adoption.

Characteristics of a good practice are:

- **It is effective and successful:** It has been proved to produce effective results towards achieving a goal. It has been successfully applied resulting in positive impact on individuals or organizations
- **It is socially sustainable:** It addresses current needs of interested parties and can be sustainably deployed in the future without compromising high level objectives and goals
- **It is technically feasible:** It is technically feasible if it can be effortlessly integrated into existing practices with reasonable effort and resources
- **It is replicable and adaptable:** It can be replicated with adaptations to a range of situations with positive results

According to the project proposal, the work is based on the review of existing problem-based learning practices that had positive impact in Greece, Estonia, Portugal, Spain, and Denmark to ensure that information gathered has a wide European footprint and is relevant at a European level. In addition, the work is extending the foreseen activities in the project

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proposal to include practices in countries beyond the ones in which HERA partner organizations are located.

TITLE	
eCity project and game.	
SUMMARY	
The main objective of the eCity project was to design, develop and validate a problem-based pedagogical methodology, supported by an online, collaborative, city-development simulation engine. Specific scenarios showcasing engineering challenges were created and embedded in the game. The methodology and game were extensively tested (more than 1.200 students) and then downloaded more than 150.000 times which gives a very good idea of the large scope of interest in this project.	
FIELD / DISCIPLINE	Engineering
DESCRIPTION	
The starting point for the project was the acknowledged difficulty that secondary education and engineering students had with mathematics and other science topics. It was then, and still is, a widespread problem in Europe as stated by several international comparative studies like PISA (PISA, 2021) or TIMMS (TIMMS, 2021). This prevented 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. This "net-generation" or "digital natives" quickly absorb information in shorter chunks, expect instant responses and feedback and want to be active in their learning. The project designed, developed, and validated a problem-based learning-oriented, online, collaborative VLE platform, based on a city-development simulation engine that stimulates the integration and continuous exploitation of Problem Based Learning. The platform was	

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used by students from secondary and vocational schools and higher education engineering schools.

The platform was integrated in a clear pedagogical methodology, problem-based learning-oriented, to ensure that the upmost relevance was given to the learning process, not the technology. Problems or challenges were fed into the platform as homework, teamwork, curricular activities, extra-curricular competitions, big or small projects, etc.

The project engaged approximately 1.250 individuals from different countries. Participants initiated their engagement at the research stage, at which:

- Higher education students and instructors contributed to problem definition
- Secondary education teachers helped design the problem-based learning methodology
- Secondary education students provided insight on the expectations from game-oriented learning

The activity was widely disseminated through small and larger scale events reaching over 750.000 individuals in the public and 45.000 in the direct target group. Conferences and other opportunities were exploited to promote project results and to present the technical and scientific validity of the project approach.

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WHY THIS PRACTICE	The project positively affected a large number of students and educators through broad validation activities. It was very positively accepted by the target sector of secondary education. Its results continue to generate interest until today with over 250.000 downloads.
COUNTRIES AFFECTED	Portugal, Greece, Turkey, Italy, Spain. Results are available at a European level through the project portal and software download platforms.
DATE	01 March 2020
AUTHORS	Carlos Vaz de Carvalho, VC

TITLE
Problem-based learning in the 1st year of an Industrial Engineering and Management program at Minho University.
SUMMARY
The Integrated Master's Degree in Industrial Engineering and Management at the School of

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Engineering of the University of Minho introduced problem-based learning in 2004. The proposed learning approach is now in its 14th year of use. This long implementation timeframe allowed the consolidation of the model for enriched effectiveness.	
FIELD / DISCIPLINE	Engineering
DESCRIPTION	
The Integrated Master's Degree on Industrial Engineering and Management program introduced the use of a multidisciplinary semester-wide problem-based learning process in the 2004 - 2005 academic year. At that time, the decision to start deploying problem-based learning received some support from the rector. The initiative aimed at introducing diversity on pedagogical methodologies deployed on campus. The methodology was initially applied during the 1st semester of the 1st year of the program. As a result, the first learning experience at the university for these students was in a problem-based learning setting. Problem-based learning contrasted with the students' prior learning experiences in earlier education levels, ranging from primary to secondary school, and represented a shift on educational design that departed from traditional lecture-based instruction in which learning is more passive. Early approaches on the deployment of problem-based learning in the Integrated Master's Degree program were designed in a top-down manner considering the constraints of existing curricula. Their implementation relied on the motivation and good will of a set of lecturers who taught 1st year courses and volunteered to build the required structure and provide the operational support for the implementation of the initiative. Subsequent implementations relied on a wider team of lecturers who mostly focused on selected project supporting courses. They also relied on staff acting as tutors and on researchers from the field of education for supporting learning activities. These individuals constituted the coordination team of the project. In the 2012 - 2013 academic year, a reformulation of	

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the Integrated Master's Degree program curriculum provided the opportunity to adapt the structure of the program to problem-based learning by creating the Integrated Project in Industrial Engineering and Management I course. The evaluation of the learning effectiveness of the problem-based learning approach has always been a concern. The feedback provided by students, teachers, tutors, and educational researchers contributed to the evaluation. To document perceptions of this diverse group of participants, a final workshop was put in place at the end of the semester. The workshop acted as a platform for evaluation data collection. Data included the results of a survey answered by students, student grades, participant answers to open questions, perceptions on the assessment model of the project, and perceptions on problem-based learning as a learning methodology. The data was collected through a discussion, which was conducted in small focus groups the results of which were presented to all.	
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WHY THIS PRACTICE	The approach has been applied systematically and has proven to be effective and successful in terms of students' skill development. The approach has been published extensively so

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	it is replicable and adaptable.
COUNTRIES AFFECTED	Portugal
DATE	15 March 2020
AUTHORS	Carlos Vaz de Carvalho, VC

TITLE
Implementation of Industrial Engineering and Management Projects in Interaction with Companies.
SUMMARY
The Integrated Master's in Industrial Management Engineering program of the University of Minho, implemented since 2005, is a model of problem-based learning design inspired by the project-led engineering education approach. Project-based learning is part of problem-based learning. In this approach, students build knowledge by implementing a project with a relatively large scope, often in groups. The initiative aims at creating contexts that contribute to increase students' motivation, solid technical competences development, and transversal, or soft, competencies necessary for the professional performance in the engineering and industrial management professions. Since the beginning of the problem-based learning implementation process there has been a strong focus on the implementation of projects with companies in the 7th out of a 10-semester of the program. This creates a specific profile of students that have the capacity to effectively engage with companies, with factory production, and with the most diverse players. In these projects, student teams strive to develop, with the support of teachers, a solution to one or more real problems posed by companies related to the

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learning results of the semester 7.	
FIELD / DISCIPLINE	Engineering
DESCRIPTION	
The Integrated Master's in Engineering and Industrial Management at the University of Minho stands out since 2005 for the integration of interdisciplinary projects in the curriculum. Currently, in addition to the final Master's project taking place in the 10th semester, the curriculum includes interdisciplinary projects at 3 different milestones of the program, specifically in the 1st, 7th, and 8th semesters. These projects, in addition to their interdisciplinary approach, are characterized by the links to professional engineering practices through problems in which student teams are challenged to design solutions during the semester using as reference the contents of the curricular units and being supported by educators and tutors. Even though the 3 interdisciplinary projects that are already part of course work share similar principles, it is important to mention that they differ from the operational point of view, considering the specificities of the context. The 7th semester project places an emphasis on practice, that is, the development of an interdisciplinary project the implementation of which requires interaction with companies. The nature of the project activities helps build knowledge on the specialty of engineering and management industrial, namely integrated production management, production systems organization II, production information systems, simulation, and ergonomic study of gas stations. The project is an independent unit in the curriculum and requires support for overlooking the work of the participating teams. Problem-based learning is based on the analysis and diagnosis of a company's production. Each team is allocated a problem of a different company and is challenged to submit proposals for improvement considering the problem parameters. Twenty companies have	

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been involved in the course over the 9-year period in which it is part of the curriculum. More than 40 teams and 300 students have already been involved in the activities. In this regard, the project stands out as being one of the most significant experiences during the initial training of students of the Integrated Master's in Industrial Engineering and Management (Mesquita, 2015).

The research carried out on the benefits of the initiative also demonstrates the importance of these projects in student learning especially in relation to the development of technical skills applicable in engineering practices.

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http://paee.dps.uminho.pt/proceedingsSCOPUS/PAEE_2017_PROCEEDINGS.PDF.

WHY THIS PRACTICE	The approach has been applied systematically and has proven to be effective and successful in terms of students' skill development and in their preparation for the integration in the professional market. The approach has been published extensively so it is replicable and adaptable.
COUNTRIES AFFECTED	Portugal

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DATE	15 March 2020
AUTHORS	Carlos Vaz de Carvalho, VC

TITLE
The impact of problem-based learning on transferable skills development in management education. The Business Case discipline.
SUMMARY
This research article addresses the effectiveness of problem-based learning in the Business Case discipline measured through students' perceptions, satisfaction, and skills development. Findings show that the development of transferable to the industry skills is the result of student interaction with the educator and a host company. This interaction is based on well-defined rules. Satisfaction is attributed to skills development as well as factors relating to assessment, clear teamwork rules, and understanding of how organizations work.

FIELD / DISCIPLINE	Management / Economics

DESCRIPTION
Business Case is a capstone course of an undergraduate Management degree. The main goal of the course is to help students working in teams to integrate the knowledge and skills developed throughout the curriculum and apply them to a given management problem or Business Case. The problem selected is typically complex and ill-structured problem. It is presented by an actual company. At the time of this research study, 6 companies had presented their management problems, ranging from improvements to the logistics operation to the launch of an on-line retail outlet.

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The course follows a problem-based learning methodology. Student teams work on the problem presented by host companies in a self-directed way. Teams are instructor-selected to reproduce a realistic workplace situation. A set of criteria is used, such as gender, language, computer skills, and more, to achieve heterogeneity within teams and homogeneity across teams. Teams work autonomously. They define their own schedule and member roles, organize work, and manage communication and interaction with the company. Each team is assigned an educator, who they meet weekly. The tutor encourages students to plan their work and discuss ground rules; monitors how students interact, discuss the problem, seek information, and make decisions. Generally, the tutor supervises the team's progress.

Teams work on average 12 hours a week for 15 weeks. They start by focusing on understanding the problem at hand and identifying the information that is required for analyzing the problem parameters and for developing solutions. As the problems presented are complex, after an initial general diagnosis teams concentrate on alternative approaches that contribute to the problem solution, often with feedback from the company. Students follow an iterative approach towards analyzing the problem, deciding which aspects to address, and developing a solution. In each step students collect the information they need through research. They then analyze, evaluate, and synthesize this information in a manner that is relevant to the case. At the end of the activity students present sustainable recommendations based on appropriate business analyses and defend their decisions to the class. This process enables students to develop and use transferable skills including information-researching, problem-solving, communication and argumentation skills for working with colleagues, educators, and industry. These interpersonal skills are developed through negotiation and dispute resolution among team members and with external parties, for example industry players.

Upon completion of the activities, students deliver a report and present their work to the

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company that introduced the learning task. Students are graded based on these results. Furthermore, students evaluate themselves and their teams through peer assessment processes using criteria such as:

- Contribution to the project implementation
- Undertaking workload
- Observing milestones
- Collaborating effectively
- Promoting team engagement
- Setting and following team collaboration rules

Peer challenges students to evaluate and reflect on their own behavior and performance and that of others. It further allows the personalization of grades among team members according to their individual contribution.

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WHY THIS PRACTICE	The approach has proven to be highly effective and successful in terms of students' skill development and in their preparation for the integration in the professional market. The approach has been published extensively so it is replicable and adaptable.

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COUNTRIES AFFECTED	Portugal
DATE	01 April 2020
AUTHORS	Carlos Vaz de Carvalho, VC

TITLE
The use of problem-based learning to prepare IT students for an industry career.
SUMMARY
This is an initiative at the Bragança Polytechnic involving students from undergraduate, Master's, and PhD programs in Computing in developing a software project required by a real client. The work explains the educational approach to training students for industry by involving them with real clients within the development of software projects. The educational approach is based on problem-based learning principles. In problem-based learning educators are responsible for creating an environment that enhances communication, teamwork, management, and engineering skills among the students involved.

FIELD / DISCIPLINE	Engineering

DESCRIPTION
The lack of preparation of Software Engineering graduates for a professional career is a common complaint raised by industry practitioners. One approach to solving, or at least mitigating, this problem is the adoption of the problem-based learning. The involvement of students in real industrial problems and challenges incorporated into formal curricula is a well-accepted means for preparing students for their professional careers. The real-world problem study approach to teaching Software Engineering has been shown

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through this work to be successful. It has helped in motivating student teams and in encouraging the development of higher quality project outcomes. The teams took seriously the importance of the problems that they were helping to solve. The approach teaches inexperienced graduate students many principles of Software Engineering, verification, and validation practices that they could be called to apply in subsequent courses or entry level jobs.

The implementation of this approach started in the academic year 2009 - 2010, although some well-controlled trials had taken place in previous years. During that academic year, students became engaged with real-life clients located at the region of the university. The real client activity area was diverse. In earlier software students collaborated with factory enterprises, non-profit institutions of social solidarity, a professional handball team, and a professional football team.

Over the past 4 years approximately 1.000 students were involved in the activities that were offered 4 times.

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WHY THIS PRACTICE	The approach has proven to be highly effective and successful in terms of students' skill development and in their

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	preparation for the integration in the professional market. The approach has been published extensively so it is replicable and adaptable.
COUNTRIES AFFECTED	Portugal
DATE	15 April 2020
AUTHORS	Carlos Vaz de Carvalho, VC

TITLE	
Economics Network	
SUMMARY	
The Economics Network is the largest and longest-established academic organization devoted to improving the teaching and learning of economics across universities, running one of Europe's best international economics education conferences. Created two decades ago it has always been focused on educational innovation, professional development and promoted best practice in economics pedagogy. The Network consists of academics from over 60 UK universities and has links with staff in universities worldwide.	
FIELD / DISCIPLINE	Economics
DESCRIPTION	
The Economics Network, besides the dedicated conferences, events and training provides a large repository of resources dedicated to economics teaching and learning. It gives teachers the possibility of using free resources to support their active teaching practices. Examples of these resources are the following:	

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- Handbook for Economics lecturers, explaining how to make student research tasks a central part of an economics course
- Handbook chapter on the use of games or simulations in teaching economics, with examples
- Handbook on overcoming barriers to active learning in lectures
- Project on embedding problem-based learning and critical skill development in the curriculum
- Project in introducing problem-based learning to a 1st year curriculum.
- Project on economics teaching and learning through the arts.
- Worksheets for problem-based learning tasks
- Sample problem-based learning exercise in macroeconomics
- Microeconomic case studies on competition and collusion
- Workshops on the use of case studies, problems, and issues in teaching economics
- Just-in-time teaching in Economics resources
- Active learning techniques: classroom exercises for Economics

REFERENCES AND MORE INFORMATION	
Sources: https://www.economicsnetwork.ac.uk/themes/activelearning.	
WHY THIS PRACTICE	This is a large academic network that supports teachers in the process of introducing Active Learning in Economics. It is highly dynamic and effective, with many participants.
COUNTRIES AFFECTED	UK and Europe
DATE	15 July 2021

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AUTHORS	Carlos Vaz de Carvalho, VC

TITLE
Projects Lab course at the Telecommunications Engineering School of the University of Vigo.
SUMMARY
This is a course in the last term of the undergraduate program in Telecommunication Technologies Engineering. The course exposes students to projects that are implemented in teams of 4 - 6 individuals who must represent at least 2 of the 4 specialization areas of the program, which are Telematics, Signal Processing, Electronics, and Sound-Image processing. Each team is supervised by 2 faculty members that enrich and facilitate cross-fertilization among different thematic areas. Students identify a real-world problem, analyze the issues involved and review the technology available and technical literature for proposing a solution. They are challenged to develop a technology-based prototype with a minimum functionality that makes it an independent, minimum, viable product that can be deployed in validation and feedback generation cycles. The course further exposes students to issues related to social impact, legislation, and sustainability.

FIELD / DISCIPLINE	Telecommunications Engineering

DESCRIPTION
The course aims at supporting the development of transversal and specific competences that students need in the undergraduate program in Telecommunication Technologies Engineering. Some skills that the course addresses are: • The ability to solve problems, to take initiative, to make creative decisions, and to

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communicate and transmit knowledge and skills considering the ethical and professional responsibility of the technical telecommunications engineering profession

- The ability to analyze and assess the social and environmental impact of technical solutions
- The ability to apply fundamental elements of economics and human resources management, project planning and management, legislation, regulation, and standardization in telecommunications
- The ability to approach an emerging problem focusing at first on its essential aspects and subsequently on the secondary
- The ability to manage telecommunication project human resources and finances
- Understanding engineering in the context of sustainable development

Students work in teams of 4 - 6 individuals on synthesizing a feasible solution to a real-world problem. It is mandatory that they develop a physical, technology-based prototype that can be deployed to demonstrate their proposed solution and receive feedback from end-users. The subject expands over 14 weeks with students working around 20 hours per week. The activities involved are:

- **Introductory activities:** These involve lectures introducing practical tips towards building skills such as oral and written presentation as well as teamwork. Agile methodologies (Edeki, 2015) used in engineering design are also explained as a means for effectively managing project implementation
- **Mentored work:** Partial review of the different projects' evolution with short presentations and discussions. This is a group activity supervised by 2 faculty members. Each week a 1-hour meeting takes place between the team and tutors
- **Problem-based learning:** This is the core of the course. Student teams engage in a project, in which they are challenged to solve real-life problems. Team members

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must closely collaborate to achieve project objectives. Teams are encouraged to develop a web site, wiki, blog, or similar to document and demonstrate their work. All team members must be able to defend the team project at the end of the course through a presentation and 2 public poster sessions

- **Presentation:** Every team must defend its project in a final oral presentation and in 2 poster sessions known as LPRO DAYS. The oral presentation can be delivered by 1 or more members of the team and must include evidence to show proof of the work developed and achieved results. At the end of the presentation all members must be available for a question-and-answer session. In addition, all team members must be present in the poster sessions, which are public and open. They demonstrate, explain, and get feedback of their prototypes. Usually, a morning session is open to all faculty, students, and personnel working in the university and also to some primary and secondary students that are interested to see the outcomes of the work. After the lunch break an afternoon session is open for local technology companies. This event is a main point for the success of the course because students are eager to demonstrate their work and are happy when they receive positive feedback. The event has significant importance for the school

The stakeholders involved in this course are the faculty of the Telecommunications Engineering School and local companies in this domain. Companies have shown a great interest in proposing problems to be solved by students and providing feedback on the proposed solutions. Some of these local companies award monetary prizes to the best ideas. Associations or organizations interested in the projects are sometimes also invited to the student presentations, including the city council, social-care associations, and more. It is a great experience for them to see what the students can achieve.

This course took place for the first time in the 2013 – 2014 academic year. Deployment continues until today.

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The solution and process adopted is based on the principles of agile and lean methodologies (Edeki, 2015). Students are asked to work towards the achievement of solutions in the form of prototypes in short cycles. Through these cycles the outcomes evolve rapidly from basic prototypes to actual products. It is important that the prototypes produced deploy telecommunication technologies solutions. Design thinking methodologies (Brown, 2019) have also been deployed in some years, but there typically is not enough time to apply this properly.

This practice has not been validated in a rigorous way. This course has had a strong impact in the school. For all students, faculty, and personnel in the school it is a n important activity that is highly anticipated as students surprise the audience each year.

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Information and pictures of all the previous editions can be seen at this link: http://teleco.uvigo.es/index.php/gl/estudios/gett/planificacion-academica/lpro.

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Rodriguez M. C., Uso de Metodos Agiles y Lean en la Realization de Proyectos en Tecnologia Tecnologia,

http://taee.etsist.upm.es/actas/2018/papers/2018S5BA05.pdf.

WHY THIS PRACTICE	The practice was selected because it has produced very good results since 2014. Therefore, it can be considered as a validated process on how to involve students working in teams towards the achievement of a successful project that involves skills such as problem-solving, creativity, taking initiative, etc.
COUNTRIES AFFECTED	Spain

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DATE	13/03/2020
AUTHORS	Manuel Caeiro Rodríguez, Martín Llamas Nistal, Fernando Ariel Mikic Fonte, UVigo

TITLE
Teaching support resources for problem-solving competences at the Universidad Politécnica de Madrid.
SUMMARY
This involves a set of resources including a methodology to support the development of problem-solving competences. This practice is based on the following premises: • Individual student research is important at the beginning of the activity • The sharing of ideas after the initial individual work can be very fruitful towards the synthesis of solutions • The review the problems and solutions by peers can contribute to the optimization of results A key point in this methodology is the selection of appropriate problems. The activity makes a distinction between exercises and problems as educational tools towards the development of problem-solving skills. Educators define the characteristics of a good problem as well as the steps that should be followed to solve it. A key part of this initiative focuses on developing the guides and resources that are necessary for assessing problem-solving competence.

FIELD / DISCIPLINE	Natural Environmental and Aeronautics Engineering
DESCRIPTION	

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The key challenge in this activity is how to support teachers in the development of problem-solving competences among students enrolled in their courses. Many teachers are not familiar with effective methods on how to approach problem-solving skill development.

The activity is implemented by the Universidad Politécnica de Madrid. It was launched in 2013.

The methodology proposes to students was "to learn by solving problems". The problems selected are in-line with the difficulty level of related course activities. The problems are more advanced than simple exercises and involve non-directive, motivating statements that facilitate the formation and development of concepts.

The aim of this work is to promote among students the right mental attitude that encourages them to learn, understand, and apply knowledge in an autonomous manner. In this regard, selected problems must be practical, meaningful, and contextualized in the current reality of the students and their future career. Learning focuses on analysis and results but, above all, resolution procedures.

As a strategy for teaching problem-solving competence the coordinators of the activity chose the original procedure proposed by Pólya (1998). The reason for this selection is that the proposed method is a very general strategy that can be easily adapted to typical problems in diverse fields of knowledge. The strategy is structured in 4 steps:

- **Problem comprehension:** Students are challenged to carefully read the problem and represent it in different ways. Then, students highlight significant data and the unknown parameters of the problem
- **Planning the solving process:** It is normally the most difficult task. It requires the establishment of relationships between data and as a pre-requisite for developing a problem-solving plan
- **Implementation of the plan:** A well-conceived problem-solving plan typically has an

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easy implementation although adaptations may be necessary

- **Assessment of both the solution and the procedure**: This step is essential for improving problem-solving learning design. Students critically examine and evaluate obtained results as well as the implementation process itself. It is important for students not to let the implementation details distract from the high-level concepts

Observing the 4 rules procedure proposed by Pólya (1998), activity coordinators have developed a set of generic rules for guiding the students on the main aspects of problem-solving processes and on the desirable order of implementation steps. In an initial stage, activity coordinators introduced a very generic procedure that integrates the relevant rules of problems solving. The resulting procedure can be applied to any problem regardless of its complexity or the solution approach selected. Each of the identified problem-solving aspects can be evaluated and allocated 1 to 4 points (from D to A) according to different criteria. The problems introduced to students may differ significantly depending on the subject and the year of studies. To compensate for that, the activity coordinators divide problem-solving competences in 4 levels, one for each year of study. Each level involves its own proper procedure with different rules, which are always based on the basic set of rules described above.

The 1st level problem-solving procedure is designed to be applied to 1st year engineering students. The procedure encourages students to address complex problems rather than individual, simpler exercises. The wording of a given task includes more information than strictly needed to solve the problem. Students are asked to select between at least 2 approaches of solving the given problem, usually one being correct and the others not. In more advanced curriculum years problem statements are more complex. Their solution can be approached in several ways, of which some may be more efficient than others.

After deciding on an appropriate problem-solving approach, in the next step students design an implementation method and evaluate its effectiveness based on a rubric that

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involves the following criteria:

- Comprehension of the proposed approach
- Application of the approach
- Justification and clarity of designed solutions
- Completion and effectiveness of results
- Efficiency of the proposed implementation
- Critical analysis of available data and possible solutions

The proposed problem-solving method was evaluated in practice through piloting conducted in the context of 4 subjects of the 1st and 2nd year of studies in the Aerospace Engineering and Natural Environmental Engineering programs. A total of 146 students participated in the pilot. Following is a summary of experiences in specific subjects.

In chemistry, problem-solving experience was exemplified with water quality global indicators. Students were challenged to elaborate a concept map with the concepts involved in these indicators and use the map in different conditions.

In mathematics, the pilot study was divided into 3 stages, in which the difficulty of the activities and the number of assessed criteria gradually increased. The study was also conducted in the statistics and river hydrology courses. A hydrology lecturer delivered a seminar on river flow concepts, such as return periods for heavy rains and expected flow. Statistics lecturers further presented ways to estimate these flows through the deployment of Statgraphics' tools. Finally, a mathematics teacher asked the students to evaluate and justify the choice of a particular estimation method.

In physics, students were challenged to calculate the calorific energy needed to increase a room temperature and the temperature descent that resulted from the reduction of insulation material.

In mechanisms, the teacher gave students the design of a cam-follower mechanism used to

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shake samples and asked them to calculate the parameters necessary for it to work properly. To address the problem, students were challenged to research information for a whole afternoon. The next day they were requested to present their solution in the classroom and submit it to the teacher.

Upon completion of their participation in the pilot study students received professor feedback and were asked to fill a questionnaire of satisfaction consisting of 22 questions. 66% of the volunteers responded, approximately 70 individuals.

Although some differences in opinion were observed in different courses students tended to agree on evaluation aspects with small variations in mean values.

More than 60% of students stated that not only had this pilot study been interesting to them, but also that the difficulty of the presented problems was adequate for their knowledge level. Most of the respondents, over 80%, were mostly or totally in agreement with the following facts:

- The proposed problem-solving learning experiences should be voluntary and affect the final grade
- Students would like to take part in similar pilot studies in other subjects
- The allocated time was sufficient
- The presentation of the task was attractive to them as a learning activity

On the contrary, students did not agree to participate to similar pilot studies in the context of their lectures.

Regarding assessment criteria, half of the respondents thought that the rubric was a proper manner of evaluating the pilot study. However, a high number of students were indifferent to the question.

Only 33% of the respondents found the problem easy. In general terms, 66% of the respondents thought that the experience was positive or rather very positive and stated

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that they would recommend to other students to participate in similar pilot studies. Only 10% of students found the whole experience negative.

From the teachers' point of view, the pilot study evolved satisfactorily, and students were especially interested in the task as a result of being challenged to solve a problem in a context that was different from that of the usual lectures.

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Pólya G. (1988). How to solve it: A new aspect of mathematical method. Princenton NJ: Princenton University. Jiménez C. F. & Tapia J. A. (2012).

WHY THIS PRACTICE	The activity has been applied in several subjects successfully, including mathematics, chemistry, and physics in Natural Environmental Engineering and mechanisms in Aeronautics Technical Engineering. The approach has been validated for the teaching of problem-solving competence. It also provides guidelines about how to select appropriate problems for addressing student needs.
COUNTRIES AFFECTED	Spain

Co-funded by the Erasmus+ Programme of the European Union

DATE	13/03/2020
AUTHORS	Manuel Caeiro Rodríguez, Martín Llamas Nistal, Fernando Ariel Mikic Fonte

TITLE
Analyzing the level of acquisition of problem-solving skills in the Business Administration and Management Program in Badajoz and Seville.
SUMMARY
Problem-solving skills are in high demand in the job market. Demand necessitates a close examination of the contribution of university studies in the acquisition of related skills. This initiative aims to assess and analyze the level of acquisition of problem-solving skills in students in the Degree Program in Business Administration and Management (Spanish acronym GADE) through the four courses in the curriculum using the Social Problem-Solving Inventory-Revised method as measuring instrument. An increase in the acquisition of skills among students as they progress through the program is observed, although without significant differences between courses. Taken together, the results show that the training provided failed to make the necessary contribution to the process of preparing future professionals in this area.

FIELD / DISCIPLINE	Business Administration and Management

DESCRIPTION
The initial problem motivating the undertaking of this initiative is the lack of assessment methods for measuring competences, particularly problem-solving skills in Business Administration degrees. Problem-solving is identified as a key competence for employers

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and students in this domain. Problem-solving skills are developed throughout the duration of studies in all courses and in different subjects.

The stakeholders involved are:

- Undergraduate students in Business Administration
- Faculty in Business Administration
- Researchers interested in the development of problem-solving skills

The initiative focused on the universities of Badajoz and Seville in the South of Spain. It took place in 2013. The implementation team worked with the problem-solving model proposed by D'Zurilla and Nezu (D'Zurilla 1982; Nezu 1999). In this model, a problem is defined as a life situation or task that an individual or group of individuals faces. The individual or group is required to introduce an adaptive reaction. An effective response does not seem immediate or available due to the presence of one or more obstacles. Problem-solving is recognized as a cognitive-affective-behavioral process in which an individual strives to identify, discover, invent, or adapt ways of coping with problematic situations in everyday life.

In the context Business Administration and Management studies, considering the information included in the teaching guides of curriculum subjects, the implementation team found a link between the problem-solving model of D'Zurilla et. al (D'Zurilla, 2002) and curricular objectives, particularly in relation to the 4 phases in which the problem-solving process is divided under the rational style. Researchers observed that certain subjects, such as Introduction to Economics and Business Mathematics, promote the understanding and use of the scientific method and logical reasoning, which are basic tools for addressing any problematic situation. On the other hand, certain subjects, such as microeconomics, focus on training the student to analyze and respond to problems and others, such as organizational theory and human resources management, are diagnosis and

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solution oriented. Students are also educated in the identification, organization, use, and analysis of information sources. They are taught to discern between relevant and superficial information in courses such as advanced management accounting, business statistics, business management, and human resources management. The use of criteria related to order, systematic work, rigor, and seriousness in approaches and resolutions is encouraged in subjects such as company law. Students are trained to be creative, they are encouraged to change, and they are instructed in decision-making that involves choosing different alternatives. They are further trained in predicting, evaluating, and interpreting expected results in courses such as behavioral economics, statistics business, models for business planning, and programming. Furthermore, students are trained in the use of instruments that help solve different types of problems in courses such as macroeconomics and business statistics. As a complement to all of the above, positive attitudes, values, and habits are encouraged in courses such as macroeconomics.

The revised version of the Inventory of Problem-Solving method (D'Zurilla et. al, 2002) was used a psychometric instrument to measure the competence of individuals to solve problems. The instrument consists of a self-report that measures the resolution of problems evaluating not only the level of capacity that a person may possess but also the strengths and weaknesses in the different key components of the process. The 5 dimensions of the problem-solving model are evaluated (D'Zurilla et. al, 2002):

- Those related to the problem orientation of individuals: positive orientation (PPO) and negative orientation (NPO)
- Those related to problem solving style: rational (RPS), impulsive vs. careless (ICS) and evasive (AS)

The rational style is subdivided, as already indicated, into 4 subscales:

- Formulation and identification of a problem (PDF)

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- Generation of alternative solutions (GAS)
- Decision making (DM)
- Implementation and verification of the solution (SIV)

The inventory is made up of 52 items and uses a Likert scale of 5 response options that range from the value 0 "not at all true to me" to the value 4 "extremely true to me". The items are distributed as follows:

- PPO, 5 items
- NPO, 10 items
- RPS, 20 items
- ICS, 10 items and
- AS, 7 items

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D'Zurilla Thomas J., Arthur M. N., Maydeu-Olivares A. (2002). The Social Problem-Solving Inventory-Revised (SPSI-R): Technical manual. Multi-Health Systems, Inc.

WHY THIS PRACTICE	The approach has been proven to be highly effective and successful in terms of students' skill development. It has been deployed in real-life learning contexts in higher education since 2013 in two universities: Badajoz and Seville. It provides

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	a measuring instrument to assess the level of acquisition of problem-solving skills.
COUNTRIES AFFECTED	Spain
DATE	17/03/2020
AUTHORS	Manuel Caeiro Rodríguez, Martín Llamas Nistal, Fernando Ariel Mikic Fonte, UVigo

TITLE	
Gamification-based learning environments.	
SUMMARY	
This initiative involves a teaching innovation based on gamification applied at the Rey Juan Carlos University in Madrid. One of the main problems in the classroom is the lack of interest of the students to prepare the topics autonomously and to use the available resources to which they have access. As a course and the complexity of a subject progress the de-motivation increases, especially when the basic concepts are not well understood. This initiative involves transforming the subject of business tax regime, which is taught in undergraduate program on Business Administration and degree programs that double with Business Administration in the Rey Juan Carlos University, into the tax game Re-Game. The objective sought by teachers was for their students to explore learning possibilities in a more autonomous way with greater involvement in their training and that of their peers.	
FIELD / DISCIPLINE	Engineering, Economics, more
DESCRIPTION	
Gamification consists of incorporating game mechanisms in other types of areas, such as	

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education. To achieve this, certain characteristics of the games must be incorporated into the design of the subject, such as:

- Short-term objectives to reach a goal
- Structure by levels
- A system of rewards and information on progress

Teachers propose a team game in which all members must be involved helping classmates to keep up without losing motivation. The method seeks to develop critical thinking and the search for consensus in proposed solutions.

In the described activity, each team was challenged to create a fictitious company and apply the knowledge of the subject to keep the company's tax obligations up to date.

The teachers organized the game into levels that corresponded to the syllabus. To pass each level, students had to:

- Individually, prepare the content of each topic and perform self-assessment tests. Upon completion, students took a test on each topic on a planned date
- In teams, students competed in groups on practical activities that involved exercises on the topic studied. The level of difficulty gradually increased at each level because of cumulative incorporation of fiscal elements

Each activity allowed students to add points and collect badges depending on the number of points achieved. The rankings were published upon completion of each level. The highest scoring teams received "excellence bonus".

To assess the results of the innovation, organizers compared the results of students from groups that applied gamified learning with others who did not. They further carried out a satisfaction questionnaire.

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WHY THIS PRACTICE	This experience shows how an emerging learning approach, namely gamification, can be deployed to support soft skills development.
COUNTRIES AFFECTED	Spain
DATE	08/04/2020
AUTHORS	Mercedes Vila, Carlos Ferro, Fernando Comesaña

TITLE
Peer evaluation and self-assessment of transversal competence teamwork at the Polytechnic University of Valencia.
SUMMARY
This activity deploys a set of resources, including quantitative methodologies, to evaluate

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teamwork and leadership transversal competence. Individuals are divided in teams. All participants must answer a questionnaire of 9 indicators related to teamwork and leadership, evaluating both their teammates and themselves. These joint results are adjusted to the ideal profile for transversal competence established by the subject teachers. With this information, teachers apply an adequacy coefficient, which allows students to be ranked from the highest to the lowest level of acquisition of transversal competence.

FIELD / DISCIPLINE	Engineering, Economics, more

DESCRIPTION

One of the great difficulties presented in the evaluation of transversal competence related to teamwork and leadership is the lack of evidence available to teachers to issue an objective and fair evaluation since it is unknown how group-work was carried out throughout the semester. This difficulty is due to conflicts that arise in the teams, subjective evaluations, the assessment of the final product but not of the processes, or ignorance of the elements of this transversal competence.

The activity addresses teachers and students of the course human resources management in the Management and Public Administration program of the Polytechnic University of Valencia.

This initiative was launched in academic year 2017 - 2018.

For the development of problem-solving capacity, the initiative proposes that the students themselves should evaluate the competition using a quantitative methodology proposed to the students themselves.

This methodology deployed is structured in 5 steps:

- **Configuration of the work teams**: The teams are created by the students

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themselves at the beginning of the semester during which they carry out various practical activities, which are used for the evaluation of the subject

- **Design of the evaluation questionnaire**: A questionnaire has been designed with 9 indicators related to teamwork and leadership. The questionnaire includes aspects of activities, deadlines, prioritization, information, conciliation, agreement, interest, ideas, and encouragement. These aspects are influenced by a rubric prepared by a group of Polytechnic University of Valencia professors, who are considered experts in this transversal competence. All aspects are integrated in learning activities teamwork
- **Data collection:** Evaluation is delivered in the classroom at the end of the semester to ensure that students have gathered enough information to issue an assessment of the group-work carried out. A template was provided to students for peer and self-evaluation. To avoid bias in data collection, the information was collected privately
- **Calculation of the ideal profile:** Teachers establish the ideal profile of transversal competence, setting a value to each item of the questionnaire
- **Calculation of the adequacy index:** The fit between the data collected from students is analyzed, both for self-evaluation and for peer evaluation, and the ideal profile is generated using the adequacy index. The results are ordered from highest to lowest. The student with the highest coefficient has the highest correlation to the level of acquisition of transversal competence

From these 5 steps, the adequacy coefficient is calculated. This coefficient is designed so that a student's knowledge is classified as being closer to that demanded by the subject as the correlation between the assessment of students in pairs or self-assessment and the educator perceptions rises. By means of this coefficient, the similarity of each student to the ideal established by the teachers is measured allowing the students to be ranked and

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conclusions to be drawn on the evaluation process.

For this study, data was taken from 7 groups made up of 4 students each and 4 groups made up of 3 students, that is, a total of 40 individuals. The actual enrollment number for students was slightly higher, however unstable teams and teams with incomplete evaluations were dismissed from analysis.

This practice has not been validated in a rigorous way. Nevertheless, the promoters of this methodology are satisfied with the obtained interesting results. They intend to continue applying it in following academic years. Furthermore, this method can be extrapolated to any other university or pre-university environment. It should be noted that the calculation of the coefficient of adequacy is different in each case in which it is applied since the ideal varies depending on the assessment of the teachers.

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WHY THIS PRACTICE	This practice is a good example of teamwork and leadership skills development and evaluation.
COUNTRIES AFFECTED	Spain
DATE	08/04/2020
AUTHORS	Carlos Ferro, Mercedes Vila, Fernando Comesaña

TITLE
Soft Skill Toolkit
SUMMARY
This is a course that aims to develop the skills necessary among graduate students for sharing ideas and thoughts related to their work and research with a broader audience inside and outside academia. The course focuses on ways for eliciting interest and engaging students in elaborate and fruitful conversation. Furthermore, the course challenges participants to put theory into practice by developing a promotional speech, practicing their promotional pitch, developing an “onion model” presentation, creating a scientific poster, and writing a project draft. Participants are encouraged to thoroughly prepare for engaging in learning sessions so that they can actively use their work along with that of

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their peers in individual and group sessions.	
FIELD / DISCIPLINE	Master's and PhD candidates and professionals from all disciplines
DESCRIPTION	
This is a 2 credit, 5 days course tailored to the needs of Master's and PhD students from different disciplines who seek to explore and develop their soft skills. It involves students actively working on their communication and presentation skills who are motivated to learn how to promote their work and their research in a more concise and user-friendly way. In day 1 of the course students are asked to present themselves and their research. In day 2 they are encouraged to present to mixed audiences using the onion model. They build negotiation and management skills and learn how to settle arguments. In day 3 of the course 5 students build self-organizing skills and their ability to work individually and in groups. They further get exposed to concepts related to innovation for change. In day 4 students discover their entrepreneurial skills. And in day 5 they engage in a discussion about career development and science.	
REFERENCES AND MORE INFORMATION	
Sources: https://www.vu.nl/en/programmes/short/winter-school/courses/soft-skills-toolkit.aspx https://skills4employability.eu/.	
WHY THIS PRACTICE	This is a typical example of an intensive course that helps develop soft skills focusing on communication, self-organization, and presentation.

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COUNTRIES AFFECTED	The Netherlands
DATE	19/03/2021
AUTHORS	Manuel Caeiro Rodríguez, Mario Manso Vázquez

TITLE	
Animations to describe algorithmic sorting techniques	
SUMMARY	
Algorithmic sorting is hard to teach as it is a complex topic that requires a vivid imagination for understanding concepts. Visualizing information in engaging ways can help explain the difficult concepts of the topic.	
FIELD / DISCIPLINE	Computer Engineering
DESCRIPTION	

The problem is that algorithmic thinking, as for example sorting algorithms, is hard to teach based on theory alone. Creative teachers deploy different mediums for visualizing how various algorithms work.

Several visualization tools and games exist on this topic. Below is a short description of them:

- **Dancing to different kinds of sorting techniques** with several examples being available on YouTube®
- The **Binky Pointer** cartoons created by Stanford University. These include fun 3-minute videos that explain the basic features of pointers and memory
- **Red-black tree,** a kind of self-balancing binary search tree in Computer Science.

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Each node of the binary tree has an extra bit, which is often interpreted as the color, red or black, of the node. These color bits are used to ensure the tree remains approximately balanced during insertions and deletions. The University of San Francisco Computer Science department has created a related game (link provided below)

- **The 7 bridges of Königsberg** problem in graph theory is an example of a vivid problem used to help visualize Euler`s analysis. Students are challenged to map a real-world problem on a graph

These practices are very well accepted by teachers and liked by students. They are used year after year and can be reused anytime.

REFERENCES AND MORE INFORMATION

Sources:

http://cslibrary.stanford.edu/104/.

https://www.cs.usfca.edu/~galles/visualization/RedBlack.html.

https://en.wikipedia.org/wiki/Seven_Bridges_of_K%C3%B6nigsberg.

DATE	11/03/2020
AUTHORS	Triinu Jesmin, TLU

TITLE

Summer practice in Software Engineering.

SUMMARY

All 1st year informatics students must complete a problem-based active learning intensive

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course with real life customers.	
FIELD / DISCIPLINE	Computer Engineering
DESCRIPTION	
All 1st year informatics students are asked to form teams of 4 and solve a real-life problem. The problems are proposed by staff members at Tallinn University, students, or other stakeholders outside the university who need to solve real-world problems. In the past, students have developed on-line shops, games, Internet of Things tasks, sets of sensors to measure the quality of working spaces, robot hands and more. The problem proposer acts as a customer during a 2-week intense study period in May or June. Students are challenged to offer the best probable solution they can. They hold meetings with their team members and with customers, just like in real-life, and work on a mutual goal. Students are overlooked by supervisors from different fields such as robotics, system administrators, multimedia, software engineers, designers, business managers, etc. Supervisors are located on-campus so they can be reached as quickly as possible. Some funds are available for buying some of the necessary equipment, such as sensors, electrical elements, gadgets, assets, and more. During the semester students attend lectures on different topics. During the last 2 weeks of the semester, they meet face-to-face to work on solutions. At the end they compile a report of what they have achieved, what learned and defend it in front of a committee. The outcome usually is an applicable solution. However, students do not always succeed.	
REFERENCES AND MORE INFORMATION	
Sources: http://www.cs.tlu.ee/~inga/TTP/.	

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WHY THIS PRACTICE	This practice is a very good learning situation for young students as they experience a real-life situation just like they will have in the future, working with customers
COUNTRIES AFFECTED	Estonia
DATE	11/03/2020
AUTHORS	Triinu Jesmin, TLU

TITLE	
Tallinn University EduSpace Lab.	
SUMMARY	
EDUSPACE is a STEAM research lab. Scientists and teachers co-create and co-research new teaching and learning methods on technology-enhanced learning and teaching.	
FIELD / DISCIPLINE	Teacher training in IT
DESCRIPTION	
Technology-enhanced learning methods are often recommended as beneficial for making teaching more efficient and improving students' future employment options. Despite the benefits of the approach, there are still some major issues. Evidence-based knowledge on the influence of technology-enhanced learning on the learning process, its outcome, and the sustainability of using these in real classroom settings is insufficient. In addition, teachers tend to avoid technology-enhanced learning methods when pursuing their instructional objectives. This results in the introduction of technology-enhanced learning approaches by technology experts and researchers, which in the long-term is	

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unsustainable.

Tallinn University's Institute of Educational Sciences works on project CEITER along with an international research group of scientists. The project is funded by the Horizon 2020 Program. Participating scientists have developed the infrastructure model EDUSPACE, which is a physical training lab, and the process models EDULAB and INNOLAB, which are long-term professional teacher development programs.

In EDUSPACE, university scientists and teachers along with educational stakeholders, the EdTech start-up sector, and the EdTech manufacturing industry design and implement TEL innovations.

INNOLABS are deployed to co-create successful methods for future-proof classroom practices.

EDULAB provides a framework for incubating TEL innovations over a period of 1 to 4 years until they are mature and ready for deployment.

The research group built around EDUSPACE acts as a strategic partner for international EdTech companies that wish to validate the impact of their STEAM offerings on student educational outcomes and to introduce related short and long-term professional development programs and training for teachers that empowers them to embed pedagogically effective methods into everyday practices. On the other hand, the group provides know-how on developing EDUSPACE type of initiatives for the benefit of other universities or industry players.

The School of Educational Sciences at Tallinn University has recently created the concept of EDUSPACE ecology, where the research perspective of scientists may meet the practical experience of other stakeholders. Activities include:

- Scientists and teachers jointly design new teaching and learning on technology-enhanced learning

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- Industry players enable field testing and feedback generation by implementing the proposed educational technology in real world learning activities
- Scientists and researchers provide mentoring and support the design of life-long adult learning innovation strategies
- Scientists and researchers coach individuals at other educational institutions on developing their own individualized EDUSPACEs

As a physical space, EDUSPACE includes:

- **Equipment:** Robots, sensors, STEAM sets, virtual and augmented reality, recording devices, cameras, and tablets
- **Staff**: Laboratory assistants, instructors, and learning coordinators
- **Content:** Courses, presentations, research projects, learning resources, and licensing

Following are some examples of courses delivered in 2020:

- Robotics-supported learning in pre and primary school for Erasmus+ international students at the Master's level leading to 3 academic credits
- Teacher innovation laboratories on long-term professional teacher development programs for in-service teachers leading to 6 academic credits
- Digital skills and math for lower high school
- Outdoor learning for the upper grades of primary school
- STEAM for pre-school
- STEAM for high school targeting non-IT students leading to 6 credits and following blended learning delivered in English and in Estonian

REFERENCES AND MORE INFORMATION

Sources:

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www.tlu.ee/en/eduspace.	
WHY THIS PRACTICE	Bringing teachers to university to test and try out novel technology is a bridge between actual classroom practices and research and development done in the field of education.
COUNTRIES AFFECTED	Estonia and partner universities
DATE	11/03/2020
AUTHORS	Triinu Jesmin, TLU

TITLE
Tallinn University Centre for Innovation in Education
SUMMARY
The conflict between a fast-changing society and a largely traditional school system has become a serious obstacle in many countries. Under various terms, such as new educational paradigm, constructivist learning, inclusive education, and interesting school, lies an inspiring motive for introducing new methods and ideas for modernizing education for the needs of the 21st century. The Estonian Lifelong Learning Strategy aims to design for change in learning. It hopes to implement "an approach to learning that supports each learner's individual and social development, the acquisition of learning skills, creativity and entrepreneurship at all levels and in all types of education". This new approach is a challenge for the Estonian education system. The Centre for Innovation in Education at Tallinn University aims to support educators and policy makers in overcoming that challenge.

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FIELD / DISCIPLINE	Teacher training in IT

DESCRIPTION

The priorities of the Centre for Innovation are to:

- Create and support networks of cooperation between scientists, educators, and trainee educators
- Design, develop, and manage modern open-learning environments and interactive classrooms
- Launch and implement R&D projects on enriching lifelong learning experiences and addressing emerging learning objectives
- Design innovative curricula and programs, including initial and continuous educator training
- Design and deliver innovative teaching approaches that are comprised by innovative learning content, technologies, and educational approaches
- Consult with educators, subject didactics lecturers, and students towards the design of effective learning interventions
- Engage foreign lecturers, scientists, and doctoral students
- Introduce systematic approaches on the development of educators´ professional identity and contribute to the creation of a recognizable and respected educator professional profile

REFERENCES AND MORE INFORMATION

Sources:

Centre of Innovation Tallinn University https://www.tlu.ee/en/hti/centre-innovation-education.

Estonian Lifelong Learning Strategy https://www.hm.ee/en/estonian-lifelong-learning-

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strategy-2020#:~:text=The%20general%20goal%20of%20drafting%20the%20Lifelong%20Learning,work%20as%20well%20as%20in%20their%20family%20life.	
WHY THIS PRACTICE	Including working teachers in the research process is a key element of these practices being included in their daily practices.
COUNTRIES AFFECTED	Estonia
DATE	11/03/2020
AUTHORS	Triinu Jesmin, TLU

TITLE	
Combining Internet of Things class with natural sciences	
SUMMARY	
In spring 2018, the Internet of Things course at Tallinn University School of Digital Technologies was combined with the Tallinn University Institute of Ecology activities to create a 3-section aquarium named EcoKit: Ecological WasteWater Treatment Kit. The implementation took place at Findhorn and included sensors and data compiled from internet sources.	
FIELD / DISCIPLINE	Internet of Things
DESCRIPTION	
During the course students formed teams of 3. Each team selected a plant or EcoKit aquarium as a field of research. Vegetation was planted in each section of the EcoKit and	

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each team added their sensors. The teams measured several different things like humidity of the soil, length of plants, temperature and light, water temperature, water-level, and turbidity. They added a live camera, pumps, and lights all of which were controllable from a website and operated in real-time. Students visualized all data on the internet. At the end, all teams published their work on a single website, where all data could be seen and correlations could be established. In addition, students posted their assignments on a Facebook group where all the others, including other teachers and interested personnel, could see the results of their work.
REFERENCES AND MORE INFORMATION
Sources: https://www.facebook.com/groups/490587227966840/.

WHY THIS PRACTICE	Combining different fields of ICT and natural sciences enables the students to think in a different way and gather and analyze data in an automated way.
COUNTRIES AFFECTED	Estonia
DATE	11/03/2020
AUTHORS	Triinu Jesmin, Jaanus Terasmaa, TLU

TITLE
Framework for Gamified Programming Education
SUMMARY
Programming is by some students considered to be of great difficulty and hard to learn.

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Programming is considered in many countries to be of utmost importance. Preparing skilled and good programmers is a high priority in many companies. The Framework for Gamified Programming Education is an Erasmus+ project that focuses on raising motivation and promoting knowledge development on programming by introducing gamified programming exercises with the possibility for automated feedback and simulations and as an interactive learning environment. This project is the first of its kind focusing on providing open collections of gamified programming assignments in an interactive learning environment.	
FIELD / DISCIPLINE	Engineering, Programming
DESCRIPTION	
Europe needs qualified developers for promoting IT services design and implementation. However, one of the bigger obstacles for many programmers is the difficulty in learning programming. This activity develops a gamified, interactive IT platform, where students or others who are learning programming and experiment with their code and get automated feedback to the exercises. The IT platform is an open platform and can therefore support anyone who would like to learn programming. The gamified approach secures the motivation and effectiveness for learning programming. The project is implemented by 4 universities: • Uniwersytet Szczecinski, Poland • INESC TEC, Portugal • Universita Degli Studi Di Napoli Parthenope, Italy • Aalborg University, Denmark The project deploys engineering approaches combined with design thinking. National studies are conducted to define the requirements for the interactive gaming platform, leading to decisions related to open access. The gamified elements go beyond the popular points, badges, and leaderboards; different gaming elements are defined per individual and	

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per course. A chat board allows social and relevant feedback between students and instructors. The gamified platform is validated by students using it and providing feedback. Challenges in its deployment include language, given that not all countries teach English courses. This results in the need to provide the services in several native languages.
REFERENCES AND MORE INFORMATION
Sources: http://fgpe.usz.edu.pl.

WHY THIS PRACTICE	The project is selected because the idea and concept of the project is the result of the long experience of the participants, as well as the result of related studies, that highlight the fact that programming is difficult to learn. The project addresses a genuine problem and provides a gamified solution to solve it.
COUNTRIES AFFECTED	Poland, Portugal, Italy, Denmark
DATE	16/5/2020
AUTHORS	Lene Tolstrup Sørensen, AAU

TITLE
A digital platform for students' development of problem-based learning competences.
SUMMARY
The purpose of this project is to support the digital experience that students inherently possess towards deploying problem-based learning in their studies. The project aims to ensure that collective experience can be transferred to students in subsequent semesters,

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with the possibility of involving educators and project supervisors. The project develops a common problem-based learning platform that publishes students' experience, critique, frustrations, and more. The project is a best practice since making experience available to all students and promoting reflection. The platform allows a higher visibility of the competences and experiences related to using problem-based learning for students and educators. The platform is new and similar platforms have not been developed earlier.	
FIELD / DISCIPLINE	Engineering, problem-based learning
DESCRIPTION	
The initial problem was that students at Aalborg University exploring problem-based learning had no place to publish their experiences, frustrations, or learning. Student expression takes place through platforms the students choose themselves, such as Facebook®, email, chat, or face-to-face discussions. These experiences can be of great importance for instructors, supervisors, teachers, as well as for students at other levels or other disciplines. However, without a platform for their publication, experiences will never be visible to others that stand to benefit from them. Furthermore, this way of discussing experiences in sort of individual silos can in some cases create negative experiences that are not addressed or can be counterproductive for learning and for perceptions on problem-based learning. In the 2018 - 2019 academic year an on-line platform named Problem-Based Learning Exchange/Stud was developed. Through the platform students can exchange experiences, get information, discuss, and receive feedback. Educators and supervisors can involve themselves and get information on how courses are perceived, how teaching and supervision can improve, and which perspectives need to be further addressed. The project promotes the development of soft skills among engineering students. Problem-Based Learning Exchange/Stud is a system inspired by StackExchange® and its question and	

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answer-based format. It allows users to:

- Ask questions
- Answer questions
- Comment on answers and questions that are already in the system
- Up-vote and down-vote questions and answers in the system

Problem-Based Learning Exchange/Stud makes use of gamification principles that allow users to collect points and through those get additional rights. Moreover, and importantly, the notion of votes allows the creation of a decentralized model of quality control.

The platform was developed by teachers from different institutes of Aalborg University. The teachers are Hans Hüttel, Dorina Gnaur, Jette Egelund Holgaard, and Thomas Ryberg, AAU.

Methodologically the project was the result of research on the use of digital platforms by students. Adaptations were implemented on an existing IT platform to repurpose it for addressing the needs of the project.

The IT platform was validated with different groups of students at Aalborg University. One of the challenges was that it was hard to motivate students to use the platform on a regular basis. Research shows that it is hard to introduce new IT systems to students who already use preexisting platforms. Typically, students consider that a new platform is just another cumbersome platform with the same purpose as that of all other platforms. However, the platform in focus was successfully applied among a 1st year group of students from different disciplines as a well-functioning service for community interaction throughout the semester. This was achieved by dedicating the platform for student use only and not as a service in which teachers and supervisors would be also engaged. The results of this work demonstrated that if the goal of an evaluation process is to gather information on student experiences during the use of an IT service, it is worth considering allowing students freedom by limiting the overlooking of their work by teachers. When a teacher is present in

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the IT service, students may perceive the experience of using the service to be similar to that of typical exercises.	
REFERENCES AND MORE INFORMATION	
Sources: https://vbn.aau.dk/da/publications/a-web-based-platform-for-building-pbl-competences-among-students.	
WHY THIS PRACTICE	This practice has been selected since this shows that it is important that information technology systems used for educational purposes must be closely integrated with the curriculum and must include possibilities for students to exchange information that is not overlooked by the teacher. This is to ensure that the students do not use other platforms and, in that way, direct resources away from the learning platform.
COUNTRIES AFFECTED	Denmark
DATE	16/5/2020
AUTHORS	Lene Tolstrup Sørensen, AAU

TITLE
Increasing collaborative communications in a programming course with gamification.
SUMMARY
At Lappeenranta University of Technology an approach has been developed for using

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gamification elements to increase online student collaboration. In a related study, a gamified online discussion system was added to an introduction to programming course with the aim of motivating the students to help each other. The actions in the discussion systems were analyzed and compared with user profiles and a student survey. The system had a positive impact on the course, increasing student collaboration, reducing response times, and making course communications 88% more efficient by reducing email traffic.	
FIELD / DISCIPLINE	Engineering /Economy
DESCRIPTION	
In the context of building programming skills, it is essential to receive feedback, answers to questions, and effectively communicate to support the learning process. At Lappeenranta University of Technology, educators have developed a gamification tool to support learning in programming. The tool included support for student collaboration and communication by supporting the implementation of assigned problems, making it possible for students to collaborate on difficult tasks, and more. A rewarding system was set up in relation to the learning goals of the course. A total of 249 students and 5 lecturers participated in this activity. Students were enrolled in Computer Science programs. The course was delivered on-line using material such as a programming guide, lecture notes, and video lectures. Furthermore, the course was supported by an on-line asynchronous collaboration system with gamification elements. All students were encouraged to discuss and ask questions or issues regarding the course by use of the gamification forum. The gamification forum rewarded the students who participated constructively with answers, comments, or good questions. Students also had the opportunity to vote up or down the content of the system, which can provide further rewards and encouraged contribution from participants. Students could show the points they collected through the system if they chose to do so.	

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Results from the study showed that student used the system weekly on a regular basis finding relevant and useful message threats for their learning. Students generally received faster answers through the system as compared to other situations where they would need to send an e-mail to the teacher and wait for an asynchronous response. The discussion system allowed students to collaborate on programming problems but also reduced pressure on educators to answer student questions as the open communication among class members contributed to the implementation of assigned activities.	
MORE INFORMATION	
Sources: https://dl.acm.org/doi/pdf/10.1145/2659532.2659620?casa_token=ctL08_RgzfMAAAAA:ITJvi-pavgoV3-bHnK5AjydGX85Y9Fkj1Cgt62rd-9tSr_kvWhfp6juzAYEVkrH6dYbqBohb-z2XzQ.	
WHY THIS PRACTICE	This example is selected as best practice since it has a novel way of looking at the need for communication and collaboration in essential courses such as programming. The work addresses a real problem and shows that the introduction of simple gamification elements can support the development of soft skills essential in programming.
COUNTRIES AFFECTED	Finland
DATE	16/2/2021
AUTHORS	Lene Tolstrup Sørensen, AAU

Co-funded by the Erasmus+ Programme of the European Union

TITLE
The teacher's role in gamification in Software Engineering at universities – or how geeks can be inspired to sing
SUMMARY
This best case is an example from Germany, University of Applied Computer Science in Fulda, in Computer Science. Computer technology is changing fast and challenges how teachers can teach as well as their understanding and knowhow of special topics. Industry demands more and more that students can analyze and reflect independently, communicate well and are team minded, and can solve different types of problems. The case example describes how teachers in Software Engineering at the university must introduce qualifications such as analyzing, reflection, and communication as part of the curriculum. The case demonstrates good examples on the use of problem-based learning and gamification principles in specific skill building situations. To evaluate the hypothesis that problem-based learning is a positive approach in education, an event was created which allowed students to engage in broad learning activities including presentations, communication, reflection and discussion, review and feedback generation, and more. The event was attended by approximately 50 students. It showed that students learned a lot through the introduction of new educational tools such as gamification. The conclusion of the study was that gamification elements create a dynamic environment for learning.

FIELD / DISCIPLINE	Engineering /Economy

DESCRIPTION
As there is much focus on introducing new teaching and learning methods online there is less focus on how to address competences such as communication, reflection, conflict resolution, and reviewing in technical courses such as Software Engineering. This work

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presents a very practical example of a field study based on an event in which students engage on building soft skills. The event deployed problem-based learning and gamification principles.

Problem-based learning was deployed in the event because it allows students to fail with respect to some elements. Also, problem-based learning is part of communication, reviewing, conflict resolution, and other elements of the learning process that were integrated in the student activities.

Gamification was used to strengthen special capabilities in the curriculum of Software Engineering itself. Points were given if, for example, the students improved software quality by finding errors and the like.

A total of 50 students enrolled in Software Engineering programs were invited for a day seminar which that was part of an obligatory course for participants in the Bachelo's in Computer Science program at the university at Fulda. It was set-up so that the teacher could organize the learning content with the students. The focus of the event was the development of communication skills. The teacher had working experience in the Software Engineering industry and used stories from real-life as part of the event. Problem-based learning principles were introduced through different activities such as presentation of technical ideas or products, discussion, review inspection, communication between customers, developers and testers, conflict-resolution, and working in distributed, interdisciplinary development teams.

Students developed Software Engineering knowledge while also exercising other skills. Student perceptions were that the combination of these was very motivating. The study concluded that students developed Software Engineering core knowledge but also practiced skills on group communication dynamics.

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From the teacher's perspective, the conclusion was that the use of activating the students demands much more effort from the teacher than a normal lecture. The organization revolves around teamwork and transforming conventional exercises into exercises that could be used during collaborative activities. As a result, educators need to be motivated to deploy problem-based learning. The study concluded that teachers need additional soft skills in order implement problem-based learning design.	
MORE INFORMATION	
Sources: http://ceur-ws.org/Vol-1368/paper7.pdf.	
WHY THIS PRACTICE	The work is a best practice example since it provides insights not only on the need to develop soft skills amongst Software Engineering students but also on the importance of building these skills among educators. The work addresses a real problem that results from the high availability of online tools, namely that educators need to build their own soft skills before supporting students to soft skills themselves.
COUNTRIES AFFECTED	Germany
DATE	16/2/2021
AUTHORS	Lene Tolstrup Sørensen, AAU

TITLE

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A stable relationship between personality and academic performance from childhood through adolescence. An original study and replication in 100.000 individual samples.	
SUMMARY	
This project was introduced by an economist who for a long time has considered that there are special soft skills and personal traits that are essential for learning in academic life. The project was designed to statistically analyze whether there is a relationship between personality traits and academic performance. Three traits were tested: • Agreeableness • Emotional stability • Conscientiousness The project is one of kind on acknowledging that how well an individual learns in academic life is dependent on how effectively certain personality traits and soft skills are developed throughout childhood and while growing up.	
FIELD / DISCIPLINE	Economics, Soft Skills
DESCRIPTION	
Not all individuals are equally good at being academic students at universities. Some students find it hard to be self-working, be motivated, and work together with others. This may lead students to drop out of their studies or struggle severely before they learn how to work effectively in an academic environment. Developing soft skills can be challenging for these students since they struggle significantly to find momentum in their learning activities and structure their work methods. Conscientiousness involves aspects of an individual's personality relating to being responsible and goal-oriented and to getting things done. These can be seen as socio-emotional skills that individuals can practice and improve.	

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In addition, the project analyzed agreeableness and emotional stability. Agreeableness relates to people's tendency to cooperate and be empathetic towards others, while emotional stability is about having a calm disposition and being resilient in the face of stressful situations.

The project showed that, for a conscientious student, skills such as agreeableness and emotional stability have no practical impact on academic performance. This means that it can pay off exercising conscientiousness as a skill for students since it is highly correlated with the academic performance.

The project methodology was based on statistical analysis of a large dataset of Danish students. The project was implemented by an economist from Copenhagen University, Miriam Gensowski.

The project results can be used by others to understand how students can perform better. It clearly shows that by strengthening certain specific soft skills students can improve their academic performance. Strengthening specific soft skills is essential for enhancing student performance.

REFERENCES AND MORE INFORMATION
Sources: https://onlinelibrary.wiley.com/doi/abs/10.1111/jopy.12538.

WHY THIS PRACTICE	This practice is selected because it shows that the soft skills are essential for learning and that by enhancing and strengthening specific soft skills, students can enhance their performance significantly. This is the foundation for the HERA project and therefore an important practice.

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COUNTRIES AFFECTED	Denmark
DATE	16/5/2020
AUTHORS	Lene Tolstrup Sørensen, AAU

TITLE
LEAP project: Lean and agile practices linking engineering higher education to industry
SUMMARY
The purpose of LEAP project is to build experience and knowledge among higher education students on emerging lean and agile industry practices empowering them to effectively transition into the professional world, focusing on engineering disciplines. The project further aims at closing the new digital divide by promoting the development of high-quality digital content for higher education linked to both academic and industry needs. • Lean practices encourage students to design solutions that meet needs while minimizing the deployment of resources • Agile practices expose students to industry cycles in which design is integrated throughout production processes, as opposed to only in the early stages of production, ensuring that the final product effectively addresses consumer needs

FIELD / DISCIPLINE	Engineering
DESCRIPTION	
The LEAP methodological learning framework introduces a learning approach for building higher education skills related to agile and lean production design. The approach enhances learning experiences for higher education students in relation to effectively deploying those skills in the context of projects related to industrial practices.	

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The framework exposes learners to industry approaches that are well accepted for designing and implementing products and services that effectively meet end user needs. LEAP project adapts industrial agile design methods to educational contexts within project and problem-based learning. Game-based approaches complement the proposed agile, collaborative learning framework by encouraging learners to role-play by simulating work practices that learners will be exposed to in the future as professionals. The core learning approaches can be seen in the root of the LEAP didactical framework is problem-based learning.	
REFERENCES AND MORE INFORMATION	
Sources: http://leapproject.eu/.	
WHY THIS PRACTICE	The practice was selected because it produced high quality digital learning games that help build industry skills. The work contributes to the EU goals of modernizing higher education through the integration of emerging learning design. It further contributes to bringing education to the digital age through digital applications developed specifically for learning, which can be used as inspiration for building additional digital content
COUNTRIES AFFECTED	Greece, Estonia, UK, Portugal, Spain
DATE	21/04/2020
AUTHORS	Christina Taka, Hariklia Tsalapatas, UTH

Co-funded by the Erasmus+ Programme of the European Union

TITLE	
ALIEN project – Active learning in Engineering Education	
SUMMARY	
Project ALIEN aims at introducing problem-based learning as a strategic educational approach in higher education for exposing students to problem-based learning benefits that help build industry and society demanded skills for the 21st century. The project is based on the premise that problem-based learning helps develop competences that prepare students to act effectively as professionals by being exposed during their studies in a problem-based learning environment that simulates the way teams work in industry. The project aims to address the challenges that inhibit the wider adoption of problem-based learning in higher education, which include: • The lack of physical labs for using digital tools in problem-based learning contexts • The lack of digital applications developed for educational purposes • The need to develop the skills of educators towards using problem-based learning in instructional contexts	
FIELD / DISCIPLINE	Engineering
DESCRIPTION	
Project ALIEN aims to establish active and problem-based learning as strategic educational approaches in engineering higher education. The advantages of active in engineering are many. It facilitates the development of foundational knowledge as well as soft skills such as analytical and critical thinking, entrepreneurial mindsets, collaboration capacity in multidisciplinary groups, and more. It prepares students for their transition from the academic environment to the world of work through scenarios inspired by real-life. It promotes the transferability of knowledge from the academic environment to the world of	

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work.

The project is in-line with ET2020 goals of modernizing higher education through emerging pedagogical design and supporting IT technologies. ALIEN aims to:

- Improve the quality of higher education by providing more motivating, stimulating, and effective learning contexts that prepare students for their professional life through the development of industry desired competences
- Implement active and problem-based learning methodologies addressing real-life issues related to science, technology, engineering, and math (STEM) concepts
- Promote the use of IT as an educational tool through a virtual learning repository in which instructors can publish structured problems related to higher education engineering principles. The problems deploy virtual games or simulations and allow students to experiment, collaborate, and communicate in an extended and multinational learning community

ALIEN introduces a holistic approach for promoting the deployment of problem-based learning. The project develops:

- Physical labs at Asian universities that allow students to experiment on problem-based learning through digital equipment
- The ALIEN digital learning repository that includes good practices on the use of problem-based learning in the form of problems the solution to which requires the deployment of digital technology
- Instructor training for building capacity on the integration of problem-based learning into educational practices
- Community building activities for knowledge sharing and exchange on problem-based learning through webinars, on-line forums, and other events

REFERENCES AND MORE INFORMATION

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Sources: http://projectalien.eu/.	
WHY THIS PRACTICE	This practice promotes problem-based learning beyond Europe to Asia. It constitutes a good example for international collaboration and know-how exchange on best practices related to problem-based learning that help build industry skills.
COUNTRIES AFFECTED	Greece, Portugal, UK, Estonia, Bulgaria, Malaysia, Vietnam, Cambodia, Nepal, Pakistan
DATE	21/04/2020
AUTHORS	Christina Taka, Hariklia Tsalapatas, UTH

TITLE
Education Technologies course – University of Thessaly
SUMMARY
The course focuses on the deployment of technology as an educational tool in lifelong learning contexts that target the needs of specific groups including school learners, higher education students, adult learners, vocational learners, professionals, and others. The course analyses traditional and emerging learning methodologies including collaborative learning, explorative learning, active learning, mobile learning, problem-based learning, active learning, game-based learning, and more. It focuses on how technology, and most importantly information technology, can be combined with emerging pedagogies towards the enhancement of learning processes and experiences in formal, informal, and non-

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formal learning. The course furthermore focuses on how technology can contribute, in combination with pedagogical models, towards the development of basic, transversal skills including analytical thinking, critical thinking, entrepreneurial thinking, problem solving, ability to work in a team, etc.

FIELD / DISCIPLINE	Engineering

DESCRIPTION

During Education Technologies, students are exposed to AL and problem-based learning in the contexts of formal projects leading to credits.

During the projects:

- Students design educational scenarios for integration into a learning game that targets engineering higher education and aims to build skills for the real world. For each scenario, students are challenged to describe the educational objectives, the skills expected to be developed, and the gameplay and experience of the users that contributes to the achievement of educational goals
- Students design problem-based learning activities for engineering education that deploy digital technology to promote exploration, experimentation, and collaboration
- Students research topics related to
    - Digital services for educational purposes
    - Research activities related to technology in education

To complete their work, students are challenged to deploy AL for understanding the needs of the target groups in relation to specific educational objectives ant themes, designing a learning solution that involves digital technology for enriching student experiences and contributing to the achievement of learning goals, and proposing methods for validating the scaffolding of knowledge. Students present their work in the classroom for the benefit

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of all and get evaluated by their peers.
REFERENCES AND MORE INFORMATION
Sources: https://www.e-ce.uth.gr/studies/undergraduate/courses/ece329/?lang=en.

WHY THIS PRACTICE	The course has been successfully delivered for over 10 years with very good results in building soft skills of students related to effective communication, presentations, team and individual work, and critical and analytical thinking. By allowing students to select the projects they will work on, the course is heavily student-centered and promotes independent learning.
COUNTRIES AFFECTED	Greece
DATE	21/04/2020
AUTHORS	Christina Taka, Hariklia Tsalapatas, UTH

TITLE
Design and Implementation of Digital Games course – University of Thessaly
SUMMARY
The course focuses on the design and implementation of digital games and covers subjects that include: what is the definition of games and play, characteristics of digital games, game taxonomies and game genres, understanding different groups of users, designing a game concept, designing elements of game worlds, designing a game story, designing game

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characters, designing the core mechanics of a game, understanding game dynamics and the experience of users, ensuring that a game is balanced according to the needs of users, introducing elements of chance, understanding the characteristics of on-line games, understanding the principles of creative play, developing marketing strategies, and more.	
FIELD / DISCIPLINE	Engineering
DESCRIPTION	
The course is balanced between theory and practice. A significant part of the course work is the design and implementation of a digital game. Upon completing the course, the students can apply game design principles to implement further games and applications. The course includes weekly laboratory work that takes place in the computer labs of the Department of Electrical and Computer Engineering. At the beginning of the course students follow tutorial examples as well as practical presentations of the functionality of popular game design platforms, such as Unity. Upon completion of this segment of the work, which spans a couple of weeks, students use the lab to design and implement their own games in teams. During lab sessions students can collaborate with their peers towards game implementation, to get help on technical questions, and to receive guidance for a smooth implementation. The games that students develop have a theme each year. In the current academic year 2019-2020, the focus is learning games for engineering higher education, although students have the option of selecting a different target group. Before implementing their game, students are called to present their game concept in class and receive feedback from their peers. At the end of the course students demonstrate in class their working games. Some of the game ideas introduced by students include:	

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- Games for building STEM knowledge
- Games for building history skills
- Games for building geography skills
- Games for exposing users to the importance of preserving natural habitats
- Games that allow users to explore museum exhibitions
- Games that promote hand-eye coordination
- Puzzle games that promote critical thinking
- Strategy games
- Games for building language skills
- Games for building spelling skills
- Games for managing emotions such as grief
- Games that challenge players to solve a mystery by putting together bits of information that they discover
- Adventure games
- And more …

REFERENCES AND MORE INFORMATION

Sources:

https://www.e-ce.uth.gr/studies/undergraduate/courses/ece420/?lang=en.

WHY THIS PRACTICE	The course is a typical example of active and problem-based learning, where students learn by doing. It not only exposes students to games but rather is uses game-design as a learning paradigm. Students are empowered to build their own digital applications with a learning context. They develop skills on project-planning, time-management, and task-management. They further build communication, presentation, and

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	interpersonal skills.
COUNTRIES AFFECTED	Greece
DATE	21/04/2020
AUTHORS	Christina Taka, Hariklia Tsalapatas, UTH

TITLE	
OnLabs – Hellenic Open University	
SUMMARY	
OnLabs is an educational 3D Virtual Environment simulating the biology laboratory of the Hellenic Open University for educational purposes. The virtual lab allows students to experiment, overcoming constraints related to lab time and equipment availability.	
FIELD / DISCIPLINE	Biology
DESCRIPTION	
Universities and medical companies face constantly the challenge of training new students and employees on the use of medical equipment and labs. However, the cost of using physical labs for educational purposes can be high. Using the labs for education subtracts from the availability of the lab for medical purposes. In addition, the limited availability of labs for medical use introduces further restrictions in scheduling, with several teams or individuals trying to make the best of the available timeslots. Another challenge in the use of physical equipment is safety. This may be manifested in two ways: • The safety of learners during the use of equipment with which they are not familiar	

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- The safe use of often expensive equipment in a manner that ensures that it will not be damaged

These limitations introduce the need for the development of digital learning applications that simulate in a virtual environment the physical activities and encourage learners to experiment in a safe environment.

OnLabs's target is to provide students and medical employees with a test-bed simulation, yet realistic, environment, in which they can experiment with virtual versions of physical equipment. The environment offers several educational advantages:

- It allows students to experiment through trial and error without any danger to themselves or damage to the equipment
- It allows the setting of educational goals that students need to complete before they are deemed to have the skills necessary for using the actual physical lab

The OnLabs digital application is aimed for use for initial training of students in the functionality of a biology lab. The digital application can be used before students are exposed to the physical lab for building early competences and becoming familiar with base equipment functionality. For example, students become familiar with the use of the microscope in a virtual setting before using the actual equipment in the lab. The application helps contain training costs by helping build student skills through a safe, high fidelity virtual environment that accurately simulates real world lab conditions.

The interaction between the user and the environment is similar that of an adventure game. Adventure games challenge players to explore. Similarly, the OnLabs environment encourages learners to use the arrow keys to navigate and the mouse to press buttons, turn knobs, use specific objects, or collect items for later use.

REFERENCES AND MORE INFORMATION

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Sources: https://sites.google.com/site/onlabseap/home?authuser=0. https://virtual-campus.eu/alien/problems/learn-the-function-of-a-photonic-microscope/.	
WHY THIS PRACTICE	OnLabs is a good example of how digital technology can enrich educational practices by providing enhanced interactivity and opportunities for exploration and experimentation. It further contributes to bringing education to the digital age through quality digital applications developed specifically for learning, which can be used as inspiration for building additional learning content.
COUNTRIES AFFECTED	Greece
DATE	21/04/2020
AUTHORS	Dimitris Kalles, Hellenic Open University

TITLE
BEACONING
SUMMARY
The BEACONING project, co-funded by the Horizon 2020 program, aims to explore the deployment of gamification for anytime, anywhere learning by exploring pervasive, context-aware techniques and technologies in problem-based learning. The project integrates technologies, pedagogical, and social perspectives in practice-based experiments that engage communities of learners, including those with disabilities.

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FIELD / DISCIPLINE	STEM
DESCRIPTION	
The BEACONING project develops, implements, and validates a digital platform that leverages cutting-edge approaches on pervasive learning, game-based learning, human-computer interaction, and learning analytics in problem-based learning contexts. The project explores and measures the engagement levels of students as a result of game-based learning design. The project develops both off-line and on-line digital tools. The off-line tools are based on mini games that encourage learners to build STEM skills through game approaches. The on-line tools explore geolocation to engage students in gamified learning paths that take place out of the classroom; students are challenged to follow a path pre-defined by the educator and to complete assigned tasks through an application that runs on the mobile phone.	
REFERENCES AND MORE INFORMATION	
Sources: https://beaconing.eu.	
WHY THIS PRACTICE	BEACONING is a flagship Horizon2020 project, the only one funded in the specific call for proposals, which develops good practices on pervasive learning through gamification approaches. It has affected a wide range of partners in several countries. It has won the Gamification Software Award.
COUNTRIES AFFECTED	France, UK, Romania, Germany, Spain, Portugal, Italy, Poland, Turkey
DATE	28/6/2021

Co-funded by the Erasmus+ Programme of the European Union

AUTHORS	Olivier Heidmann, UTH

Co-funded by the Erasmus+ Programme of the European Union

6. Current use of information technology in problem-based learning

The HERA project aims to develop a game-based environment that supports the development of problem-solving skills among higher education students. In order to inform the design of the HERA digital learning intervention, a review of related work on information and communication technology-based services in problem-based learning contexts was conducted. This section explores the use of IT-based solutions for supporting the development of soft-skills. Nowadays, IT-based tools are usually involved in the teaching of university courses often in the context of blended-learning. 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. The following sections explore different kinds of IT-based solutions that have been described to support teaching and training of soft skills.

6.1 Serious games

The use of games in learning and in the development of problem-solving skills has been recognized by existing literature (Proctor & Justice, 2016). The use of games in learning has a main advantage over traditional education: practice precedes theory. Under this assumption, the learning process is designed for solving situational problems, whose emergence is controlled by the game. In contrast to this, traditional learning systems promote an educational paradigm focused on the educator as the center agent of the action and less as a facilitator or mentor of knowledge and learning experience.

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Serious games enhance problem-solving skills development by exposing students to different situations and challenges, making it possible to put learning into practice. A recently published book (Dell'Aquila et. al, 2016) describes examples of educational games for problem-solving skills development in digital environments. Most of the examples involve role-playing, which is a form of simulation.

Another study (Sousa & Rocha, 2017) presents the results of an analysis of the benefits of game-based learning towards the improvement of problem-solving skills. Game-based learning is a concept that is structured around a learning process that deploys a specific game as the main pedagogical tool for skill development. The analysis focused on a course that was structured on a social game, namely SimCity Social, with the goal of developing problem-solving and project management skills. The goal of the activity was to use a game that could provide rich contexts and scenarios through which learners could develop leadership, time management, and team management skills. Furthermore, the authors describe the deployment of another game, namely the Hotel Management Game. The game simulates key activities and operations for managing a hotel, as shown in the figure below. There are four player roles in this game, i.e., the marketing role, the front office role, the housekeeping role, and the food and beverage role. A process flow diagram using simulation techniques has been developed for each player role identified in the game architecture. The simulation embedded in the game ensures the representation of realistic scenarios that occur in hotel management, with the related real-life activities having been coded into the game flow diagram.

Additional work on deployment of serious games for the development of soft skills is implemented in some Erasmus+ and Horizon 2020 projects. Examples are described below.

The DEVELOP project (DEVELOP project, 2016) built a serious game to build and evaluate leadership competences. The player is immersed in an authentic workplace context. The interactions with the virtual team members help identify the player's preferred leadership

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style. The player also fills out a questionnaire to determine how she thinks of herself as a leader. When the player completes the leadership journey, she receives a report that will provides insight into her perception of herself as a leader compared to her leadership style based on her decisions in the simulation.

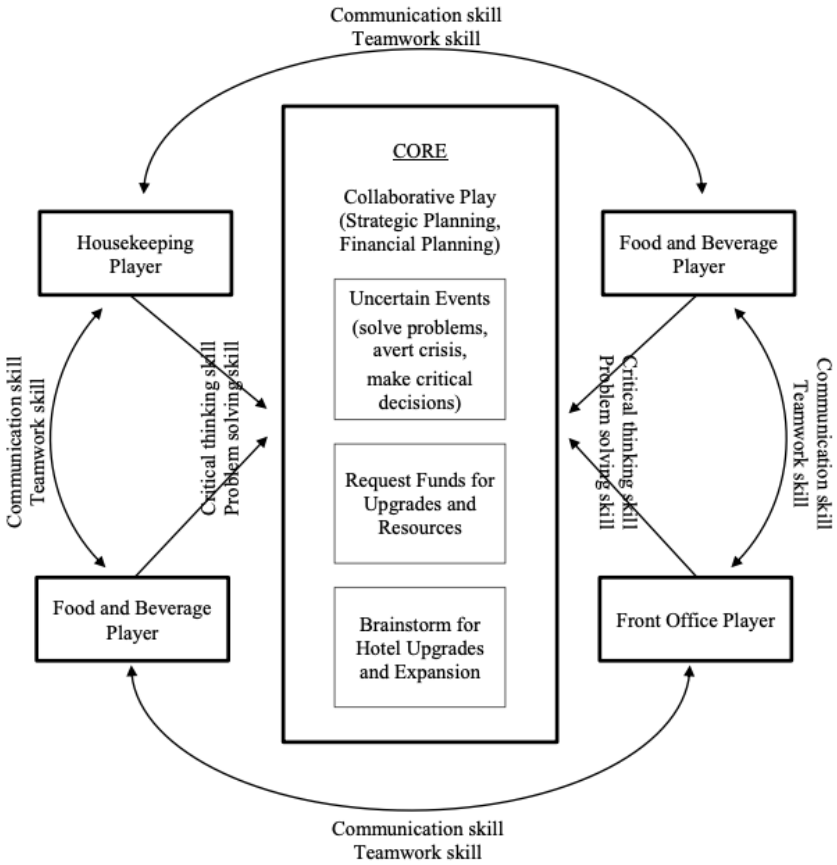

Figure 8. Board game architecture for the Hotel Management Game (Sousa & Rocha, 2017).

The Modes project (Modes project, 2020) developed a prototype of serious game that aimed at building communication, negotiation, and team work skills. The approach taken to develop the serious game included three different pedagogical concepts: exploratory, experiential, and game-based learning. These concepts reflect the paucity of existing research linking pedagogic elements to both learning requirements and technical features.

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Similarly, in the private sector it is possible to find companies that work with serious games to support problem-solving skills. GameLearn is a Spanish company (GameLearn, 2020) that develops serious games to support soft skill development, including problem-solving, in the corporate sector. Recently, the company produced Echo, a serious formative game about coaching in which the student assumes the role of a trainer to help an important public figure launch an international level treaty to eradicate plastic from oceans. The game includes three training sessions, through which the player tests his skills and abilities to help his client identify objectives, analyze reality, explore alternatives, and define an action plan. Throughout this experiential learning process, the student discovers important information and tests his coaching knowledge.

6.2 Simulations

A simulation is a simplified representation of the real-world in which a problem is defined by a set of inputs and outputs and the relationships between them (Gilbert & Troitzsch, 1999). The use of simulations and simulation-based learning has been extensively explored as an appropriate approach to build soft skills, such as problem-solving, including in large classes (Janssen et. al, 2016). Following are some examples described in the literature.

The first analysis (Frank, 2019) describes the use of enterprise simulations as an educational tool to support the development of problem-solving skills. The work describes a set of organizational behavior activities that were integrated into and delivered through simulations. The simulations include aspects of group performance, group dynamics, and team member satisfaction as well as personal growth activities.

Another work (Schutt et. al, 2017) introduces a simulated digital role-play for teaching healthcare soft skills. The work is based on a chatterbot programmed in AIML to behave as a virtual patient and recognize and respond to specific diagnostic questions posed by students. The simulation design features an editable conversation tree that allows course administrators, namely educators or instructional designers, to prompt, record, and score

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student responses in text-based interactions. The software also allows administrators to select both “reaction” animations that are presented immediately after a student has made a selection and “idle” animations that reflect the mood of the client/patient. Reaction animations include “happy”, “sad”, “yes”, “no”, “angry”, and “confused”. “Idle” animations include for the time being “disengaged”, “neutral”, and “engaged”.

On the other hand, a recent work (Bareli & Naso, 2017) describes what the authors define as the gold standard for soft problem-solving skills development: a simulation in disaster preparedness and relief. The work presented constitutes a full-scale high-fidelity simulation in which teams of rescuers are required to proceed along different phases of a critical situation. The work uses the Laerdal Sim Man 3G patient simulator.

Another work (Levant et. al, 2016) analyses the role of business simulations in developing 11 soft skills in economics education. Business games are regularly used in higher education as learning tools in management, strategy, and finance training (van der Merwe, 2013). They vary in level of difficulty ranging from introduction to management games, namely simple, general simulations that introduce a small number of variables and enable students to address the main issues involved in managing a business, to more in-depth games designed to develop skills on a specific area of corporate management, such as marketing or accounting, and immersion games in which participants receive more variables to immerse them in a complex environment intended to simulate the operation of real-life organizations. Some business simulations are based on team and group-work, where teams of students are asked to assume the role of managing an organization (Barth & Géniaux, 2010). This type of simulation thus calls for teamwork and decisions on all of an organization’s functions enabling students to build problem-solving, and more generally, soft skills.

Finally, the S-Cube project explored the use of online roleplay to promote soft sills development. This experience was published in a book (O’byrne et. al, 2014).

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6.3 Gamification

A common complaint of many educators refers to the fact that soft skills, such as problem-solving, are very difficult to be taught in an on-line course. Gamification has been proposed to tackle this situation. This approach involves the creation of a special online environment that mixes content and interactions with game elements to create an optimal stage for learning in an easy and fun way. Using gamification for online courses involves game or play elements and game-design techniques, such as score and points, challenges, progress bar, and leader boards. On-line learning platforms, such as Moodle, include plugins with numerous gamification elements that can be used to gamify on-line courses.

An example of gamification in learning (Dochie et. al, 2017) is an on-line course focuses on developing soft skills combining gamification and scenario-based learning. The course is named “Skill Generator Assessment Game”. The game design includes both a traditional on-line learning part, based on course presentations and lectures, and a game-like assessment that aims to create a game-like experience for learners. The assessment uses interactive content and scenario-based learning to develop the game experience. Also, gamification elements such as points and leader boards are included.

6.4 eLearning environments

Beyond the use of specific tools as the ones covered in the previous sections, related research activities have been developed to create complete e-learning environments. This is the case of two Erasmus+ projects:

The SKILLS+ project (Skills+ project, 2016) developed an e-learning platform focused on these soft skills (Szilárd et. al, 2018). The proposed e-learning platform includes different types of learning resources and tools that range from the more traditional reading resources to videos, real-world tips and tricks, and self-reflective exercises. The project proposes a learning space with a storyline inspired in an old clipper roaming around a “Sea of

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Knowledge", where hidden treasures and opportunities can be discovered on different islands. The hidden treasures are skills that enable the learner to navigate effectively, work well with others, and achieve goals. Despite the attractiveness of this introduction, the learning space does not involve any kind of game but the resources in the form of readings, videos, and exercises.

The DEVELOP project (DEVELOP project, 2018) created a personalized learning environment, namely an online environment for users such as employees, people managers, and strategic HR in medium and large companies who want to receive career guidance and actively develop their career. The environment offers services such as the assessment of transversal competencies such as leadership, problem-solving, communication, critical thinking, and more, helping employees discover their strengths and further develop their careers. The product of the project is intended to be a for-profit tool for medium to large companies. Transversal competencies are not solely developed by participating in on-line courses or classroom activities since the transfer of acquired knowledge into practice is not ensured. The project created the DEVELOP Social Learning Tool, an on-line tool which facilitates self-directed informal learning and competency development supported by a learning community. The tool offers various features to guide and motivate users to apply knowledge in practice. A coach can use the Social Learning Tool to prepare learning activities that focus on a certain transversal competency. An activity consists of various small tasks or challenges on which learners may work individually or be supported by a community of practice, when necessary, in their daily work.

Other activities in this category involve a kind of blended-learning approach that combines traditional, face-to-face activities with technology-enhanced learning. One work (Mokwa-Tarnowska et. al, 2019) describes experiences on the use of Web 2.0 software tools to support on-line collaborative projects for enhancing soft skills, such as problem-based learning. The work targets on Civil Engineering students. The proposal involves students

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working in collaboratively in groups of 3 - 4 individuals during a 3-week project. Projects involved challenges such as:

- Preparing an interactive poster on accidental discoveries or inventions. Students were asked to produce a multimedia poster, present it in class, and host a discussion based on it
- Compiling specifications on an apparatus or equipment invented by the students themselves in the form of a wiki and then advertising the product in class
- Devising future applications of virtual and augmented reality. Students were required to collect data on which to base designs and resources for demonstrating their solution in a presentation

To support students, the project proposed using website development and data publishing technologies such as the Moodle wiki tool, Thinglink, mural, quip, and easel.ly, which are described below:

- **Moodle wiki:** A typical wiki module included in Moodle. It supports collaborative work on a collection of documents
- **Thinklink:** A content authoring tool that allows the creation of interactive and attractive content. Users can enrich content by adding links to videos, music, pictures, web pages, and more
- **Mural:** A tool that supports online brainstorming by enabling group remote collaboration
- **Quip:** A collaborative productivity tool for access through mobile apps or web browsers. It allows the collaborative creation and editing of documents and spreadsheets
- **Easel.ly:** An info-graphic authoring tool that supports the creation of attractive posters

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Another related activity (García-García et. al, 2016) focuses on promoting the learning and assessment of teamwork skills through on-line environments. The Evalsoft system is based on a blended-learning approach that integrates games and role-playing with problem-based and collaborative learning design. Students execute a series of tasks in groups working towards solving a problem. The system runs on a service that is based on Moodle adapted with new plug-ins. The service runs on a private server to facilitate teamwork management and evaluation. Collaboration skills are developed through blended or remote tasks in which the leading role in each mission is rotated among team members. Each team organizes itself, collaborates, and self-regulates to solve the proposed mission under their teacher's guidance. Teams are comprised by three to five individuals that have been selected based on their learning styles using Vermunt's Learning Styles Inventory (Boyle et. Al, 2003). The aim of this team selection process is to achieve self-regulating teams. Groups are heterogeneous internally in terms of the autonomy level of team members. They are homogeneous in relation to the other groups in the classroom for ensuring balance and effectiveness in all teams. Students are assigned a functional role with specific tasks for which they are responsible on behalf of their team.

The Evalsoft system has been designed for incremental development in five stages as demonstrated in the following figure. Project implementation is a continuing process, which means that once a team mission is completed a second iteration with a new mission can be initiated.

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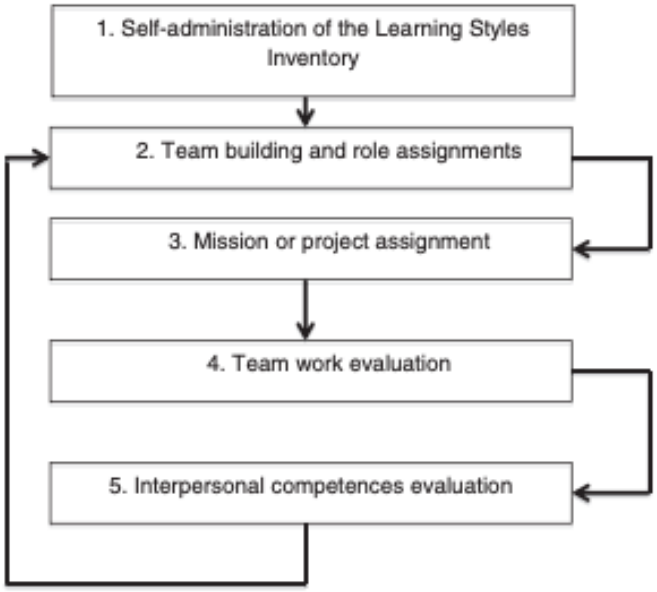

Figure 9. Evalsoft system stages (García-García et. al, 2016).

6.5 MOOCs and open educational resources

Massive Open Online Courses (MOOCs) are also used to support the development of soft skills. MOOCs target large groups of students in on-line learning contexts. They are based on the delivery of content, particularly video-based, and on the performance of continuous assessment activities. Hands-on activities and learning by doing based on real-life cases are also typically involved (Mullen et. al, 2017). Collaboration facilities enable users to work effectively in teams (Jong, 2016). Assignments are often collaborative. Furthermore, peer evaluation among teams is also a typical activity in MOOCs.

It is possible to find MOOCs that focus on different kinds of soft skills, including problem-solving. Learning and innovation skills are covered to a great extent. Communication is the most representative skill developed by MOOCs. Attention is also paid to critical thinking and problem solving. The extensive focus of MOOCs on these skills is the result of them being some of the most desired competences in the labor market (Cinque, 2017). In relation to life and career skills MOOCs in the business and management field focus on the development of

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leadership and responsibility, initiative and self-direction, and productivity and accountability competences.

Some work has been specifically devoted to the identification of MOOCs and open educational resources designed for the development of soft skills, including problem-based learning. Examples are presented below.

The eLene4work project (eLene4work project, 2020) focused on the selection and definition of soft skills, including digital soft skills, and proposed activities and practical tools for fostering the development of student skills through MOOCs and open educational resources. Another work (Puhek & Strmšek, 2019) analyzed MOOCs in the field lifelong learning skills for the 21st century with emphasis on soft competences. In total, 829 MOOCs were analyzed regarding the ability to build soft skills. The MOOCs considered in the analysis were hosted on 39 different platforms. Of these, 6 platforms hosted 84.3% of all analyzed MOOCs:

- Coursera
- edX
- FutureLearn
- Canvas
- OpenSAP
- NovoEd

6.6 Virtual reality and augmented reality

Virtual reality refers to presenting the senses of an individual with a computer-generated virtual environment. It is a simulated experience that may be similar or completely different from the real-world (Wikipedia, Virtual Reality, 2021, Virtual Reality Society, 2021). Augmented reality, on the other hand, overlays computer information on the real-world in real-time (Scientific American, 2021). Virtual and augmented reality technologies are being

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explored as training tools for developing soft skills. In most cases, they expose users to games or simulations that can be experienced in an enriched, immersive, or augmented way.

The existing projects that involve using virtual and augmented reality to support soft skills development are usually research initiatives. They are not used in educational settings in a regular way. Some of these projects are described below.

One work (Bórski et. al, 2018) presents development and test procedures of virtual reality systems for building soft skills. Specifically, the work presents the Virtual Quality Toolbox. This is a virtual reality solution that allows employees of small and micro-production companies to effectively gain knowledge on the application of quality management tools in practice. Building work experience on a selected tool requires users to perform activities in an actual production environment, including listening to a coordinator, locating a specific object, or performing a set of actions with it. The toolbox content is presented through a virtual character, namely the production master.

Another work (Hickman & Akdere, 2017) developed experiential case studies involving virtual simulation modules that immerse students in intercultural leadership scenarios. The simulations were recorded through the following.

- 360-degree cameras and real actors
- Computer generated characters

Another activity (Pinzón-Cristancho et. al, 2019) presented an educational strategy based on gamification for the development of problem-solving skills among engineering students through the simulation product development processes in a virtual reality environment. The activity was based on the popular game Second Life. The virtual environment allowed the representation of conditions very close to the ones implemented in industry, which helped promoting positive interactions among students encouraging them to overcome apathy and fear and to take action. This approach resulted in very positive perceptions.

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Finally, a recent work (Rafiq & Hashim, 2018) described an augmented reality game used to support the development of 21st century skills. The game is used primarily to teach English as a second language; but in the process it also contributes to the enhancement of the acquisition of soft skills.

6.7 Skills assessment through IT

The assessment of problem-solving skills can also be supported through IT tools. The Measuring and Assessing Soft Skills (MASS project, 2016) project outlined the importance of using different approaches of assessment for different groups of individuals.

One work (O'Connor et. al, 2016) introduced the results of the Grading Soft Skills (GRASS) project focused on representing problem-solving skills of learners in a quantitative, measurable way so that these skills might become the subject of formal validation and recognition (GRASS project, 2013). The work proposes a technological infrastructure to allow educators to continuously support, observe, assess, and acknowledge the development of student's soft skills. The infrastructure is based on self-assessment, peer observation, and teacher evaluation. The key point is to try to balance, weight, and triangulate the objective and subjective evidence of soft skill acquisition ensuring the validity and reliability of the accreditation of soft skills. The proposed technological infrastructure is based on the accreditation of soft skills with digital badges. The technological platform used to support the badge management was WordPress. The BadgeOS plugin for WordPress can be bi-directionally associated with Credly (Credly, 2020), a solution to share credentials. This enables the sharing of badges via professional and social media platforms. In addition, details of the badge earners and the requirements for achieving a badge can be stored as meta-data within the file itself. This is a key point to support transparency.

New technologies such as learning analytics and augmented reality are also explored to support problem-solving skills assessment. Research on the effects of wearing smart glasses

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on human behavior took place some years ago (Wang et. al, 2015; Tien et. al, 2014). More recently, Cukurova et. al (2019). It analyzed audio recordings for supporting the assessment of mentoring capabilities. Using this solution, it is possible to extract key features of the emotional and affective state of the subject.

6.8 Analysis

A first conclusion of the works described in this section is that the development of problem-solving skills through IT-based support is a key topic. Particularly in the context of Erasmus+ projects there has been a lot of interest in designing tools that facilitate the development of this kind of competences. A variety of tools and approaches have been attempted.

Many initiatives involve the use of games and simulations that enable the design of learning activities in which learners can experience the application of soft skills in a manner similar to real life. These applications can be used in a blended-learning way but often they are also used in classroom settings. The development of these games is hard work from the technical point of view. In addition, they are very specific, with each game focusing on some skills. Using games in instructional processes may require some level of technical preparation by educators for their effective integration with other activities such as debates, analyses, assessment, etc. Therefore, games are not directly transferable and scalable across educational institutions. Some attempts of developing games based on virtual and augmented reality technologies have also taken place, but they are still at an early research state.

There is also another group of IT solutions that are used to support and promote soft skills in the context of classroom activities, namely gamified solutions and e-learning environments. In the former, gamification is used mainly to motivate students and engage them in teaching and training. Clearly, soft skills, such as problem-solving, are very different from typical formal knowledge. Keeping learners motivated towards the development of problem-solving

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capacity is important for building the problem-solvers of tomorrow. In the latter case, tools such as collaboration, communication, and production facilities are used to support the development of student activities. These are not specific tools for the development of soft skills. Rather, in many cases they are used for other purposes as well, including the teaching of fundamental curricula knowledge.

Finally, the assessment of soft skills deserves a special comment. It is a hard part of an educator's work. Some projects and activities describe methods for capturing data from educators and peers and manage them to facilitate global assessment. IT-tools can be helpful to support these tasks. The use of electronic badges has also been considered as an appropriate tool through its gamification component. The difficultly in these solutions lies in the definition of the assessment framework, namely, what information should be collected and what the criteria are for assessing. New technologies such as analytics can play a significant role supporting or performing automatic assessment, but the existing solutions are still at a research state.

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7. Student expectations from problem-based learning

The good practice analysis presented in the previous sections constitutes a literature review. Establishing good practices is important for ensuring that past work in the field of study is considered. To complement this work through real-life data, a questionnaire-based study took place aiming at establishing student expectations in relation to the development of skills required by industry and society in the 21st century. The questionnaire was distributed to higher education engineering and economics students in Greece, Estonia, Portugal, Spain, and Denmark.

7.1 Description of the participants

Following is a description of the participants at each pilot site:

7.1.1 Students in Greece

In Greece, were enrolled in the Educational Technologies course that is an elective in the 3rd year of the 5-year curriculum of the Department of Electrical and Computer Engineering. Approximately 120 students engaged in the course in the 2019 – 2020 academic year. In the 3rd year of their studies, students have completed basic, core courses and are able to participate in electives, such as the Educational Technologies course.

Before answering the questionnaire, students received a presentation of the HERA project, its objectives, and activities at the beginning of the semester. They further received lectures on emerging pedagogical design, including problem-based learning, and its benefits towards achieving educational objectives in line with industry and societal needs. Then, students were allocated a few weeks for completing the questionnaire.

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7.1.2 Students in Estonia

In Estonia, the students involved in the study were enrolled in the School of Natural Sciences and Health and specifically the Integrated Natural Science and Environmental Management programs. Students were in the 1st or 2nd year of their undergraduate studies.

Before filling the questionnaire, students were given a presentation about the HERA project, methodology, and what skills targeted. The HERA game was presented and explained for students during the lecture. Students filled the questionnaire after the lecture as homework.

7.1.3 Students in Portugal

In Portugal, the students involved in the study came from 2 schools of the Porto Polytechnic, the School of Engineering and the School of Management. They were enrolled predominantly in the 1st year of the Master's degree in Computer Engineering and in the 3rd years of the Bachelor degree in International Trade.

Students were given a presentation of the HERA project and on the pedagogical methodologies that were involved. They were also informed about the different skills and competences that were considered in the scope of the study. Students were given the link for the online survey in Portuguese and were asked to answer it in two working days so that the effect of the presentation did not fade away. After two days, students were reminded to complete the survey.

7.1.4 Students in Spain

In Spain, the students involved in the study were enrolled in 2 different fields. The first group included students attending the course on Creation and simulation of Companies in the undergraduate program on Business Administration and Management. The second included students attending the course Projects Lab in the undergraduate program on

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Telecommunications Engineering Technologies. The engineering students have a more technical profile than their Business Administration and Management peers. In both cases, students were enrolled in the 4th year of their curricula. They had a good understanding of the desirable competences and learning objectives targeted in their studies. The average age was 21 and a majority were male (61%).

Before answering the questionnaire, students received a presentation of the HERA project, its objectives, and activities at the beginning of the semester by educators that are directly involved in the project. A presentation introducing the project problem, goals, and proposed outcomes was delivered, putting them into context.

Students were allocated a few weeks for completing the questionnaire. A Spanish version of the questionnaire was distributed to the students electronically. Students were allowed to answer the questionnaire at their leisure, at any time before a scheduled deadline.

7.1.5 Students in Denmark

In Denmark, students were enrolled in the Electronic Systems Engineering program. They have a solid and profound background in technology and programming. They have been exposed to problem-based learning through integrated pedagogies. More specifically, the students were enrolled in Master's in Cyber Security, Innovative Communication Technologies and Entrepreneurship, and IT in Communication and New Media programs in Copenhagen. The Master's program in Cyber Security teaches network and software cyber security. The program focuses on a combination of technology understanding and digital communications, transformation, and leadership. The Innovative Communication Technologies and Entrepreneurship program applies an interdisciplinary approach to teaching technologies in combination with developing understanding on market needs and how a business can build on innovation. Finally, the IT in Communication and New Media

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program focuses on building essential understanding on technology, networks, and their link to markets, users, and their needs.

Learning is closely related to industry needs through complex problems that have a broad scope beyond technology. The activities highlight the importance of markets, users, energy, and sustainability to mention a few of the topics covered. They expose young engineers to the high demands of the IT sector in Denmark and internationally.

Participating students had already built an appreciation for the necessity of soft skills in the context of group-work in industry settings.

Due to COVID-19, questionnaires were sent students via email with an explanation on a request to fill-out the survey. The email communication included a small introduction of the HERA project. The email was sent to all students at the above programs, approximately 100 in total. In addition, students were informed about the survey and its objectives through their educators during class.

7.2 Participant demographics

A total of 184 participants answered completely the survey. The demographic distribution is described below.

7.2.1 Country of Origin

Responders in the study are from Greece, Estonia, Portugal, Spain, and Denmark. The distribution of participants among countries is presented in the following table and figure.

A few other countries were indicated either by mistake or by carelessness. As the questionnaire was not searchable on the Internet it was considered that the data from these questionnaires was also relevant and was included in the analysis.

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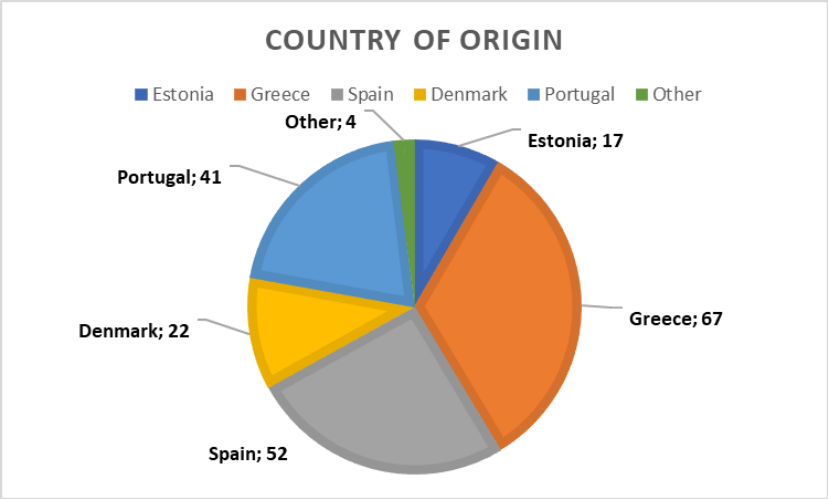
Country of Origin	#
Estonia	17
Greece	67
Spain	52
Denmark	22
Portugal	41
Other	4
TOTAL	203

Table 3. Country of origin of questionnaire responders.

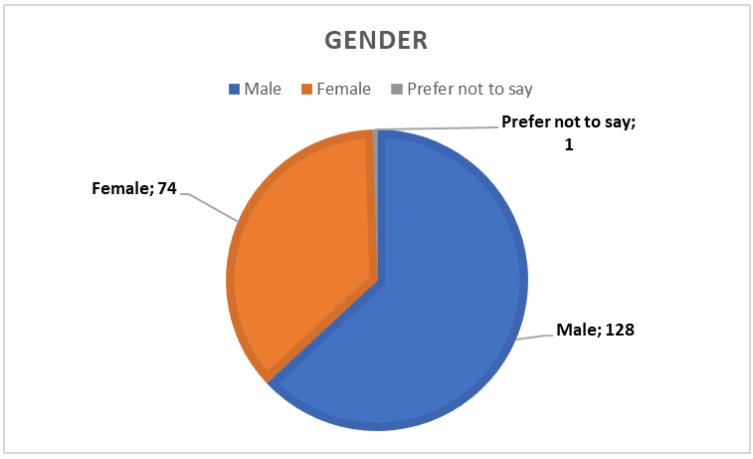


7.2.2 Gender

In terms of gender, there was a clear predominance of male students (63.1%) which is not surprising as the majority participants were engaged in engineering disciplines, which typically enrolls more male than female students.

Gender	#
Male	128
Female	74
Prefer not to say	1
TOTAL	203

Table 4. Gender distribution of questionnaire respondents.



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7.2.3 Age

Students were mostly concentrated in the late teens and early twenties, which is the typical age of higher education participants.

Age	#
18	21
19	23
20	19
21	40
22	28
23	15
24	10
25	9
26	11
27	5
28	3
29	2
30	1
31	4
32	1
33	2
34	0
35 or more	9
TOTAL	203

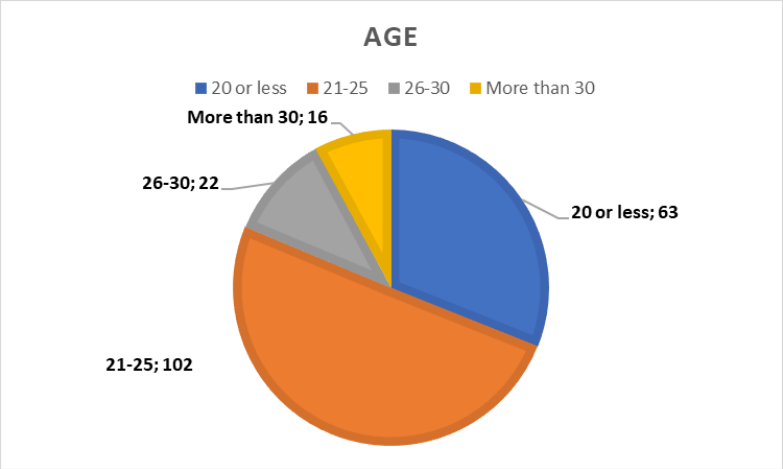

Table 5. Age distribution of questionnaire respondents.

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Some answers refer to ages over 35, which might indicate that some teachers also answered the questionnaire.

7.3 Perceived importance of future skills

Students were asked to provide input on the importance of specific skills in engineering and economics education. The skills introduced in the questionnaire are the ones identified and analyzed in section 3 of this report that focuses on the identification of desirable skills for young scientists in engineering and economics. The purpose of the question is to provide students with an opportunity to identify which skills in this comprehensive list is more relevant to them for their studies and future professional engagement.

Students classified each skill in terms of perceived importance on a scale from 1 to 5, with 1 corresponding to “not important” and 5 to “very important”. Students also were offered the possibility of choosing “don’t know”, which explains why the sum is not equal for all skills.

Overall, all skills were considered as relatively important or important. The highest rated skills were “digital literacy”, “independent and autonomous learning”, “willingness to learn”, “integrating and synthesizing information”, “open mindedness”, “creativity and adaptability”, “openness to other’s ideas”, “planning”, “collaboration and teamwork, often in multidisciplinary teams”, “implementing and assessing the effectiveness of a solution”, “being a listener”, “transferring knowledge to the real-world”, and “problem solving” while the least rated skills were “economics and financial literacy”, “assertiveness”, and “health and wellness literacy”.

	1	**2**	**3**	**4**	**5**	$\overline{X}$
Digital literacy	1	12	24	58	81	4,17
Information and media literacy	2	8	32	67	64	4,06

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Health and wellness literacy	10	22	40	64	39	3,57
Formal, basic knowledge in engineering	12	24	32	44	68	3,73
Economic and financial literacy, entrepreneurialism	7	22	55	50	44	3,57
Ethics	7	16	31	50	69	3,91
Global awareness	2	5	40	54	74	4,1
Independent and autonomous learning	0	2	29	58	93	4,32
Willingness to learn	0	5	16	52	109	4,46
Integrating and synthesizing information	1	3	30	69	77	4,21
Evaluating information particularly when coming from diverse sources	0	11	32	57	81	4,15
High-level thinking	2	5	26	63	85	4,24
Critical and analytical thinking	1	5	16	60	98	4,38
Innovative thinking	3	8	24	58	87	4,21
Open-mindedness	2	8	16	45	107	4,39
Creativity	3	7	24	71	77	4,16
Flexibility and adaptability	0	7	22	63	90	4,3
Openness to criticism and feedback	0	11	25	63	82	4,19

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Openness to others' ideas and thoughts	0	7	17	63	95	4,35
Initiative	2	10	36	68	64	4,01
Perseverance	2	8	32	71	64	4,06
Self-direction	2	7	34	79	57	4,02
Self-discipline	1	11	24	76	68	4,11
Planning	3	10	27	49	90	4,19
Ability to prioritize	2	11	26	54	85	4,17
Assertiveness	7	15	45	62	40	3,67
Being positive	10	10	41	49	71	3,89
Sense of quality of work	3	5	31	60	81	4,17
Social interaction and empathy	0	13	46	62	58	3,92
Being a listener	2	7	26	71	74	4,16
Collaboration and teamwork, sometimes in multidisciplinary teams	0	3	22	64	91	4,35
Leadership	2	10	52	63	54	3,87
Oral and written communication	2	7	35	60	74	4,11
Transferring knowledge to the real world	3	10	39	58	71	4,02
Presentation skills	5	10	58	55	53	3,78
Problem-solving	0	3	20	65	92	4,37
Providing clarity to problems	1	6	26	62	86	4,25

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Analysis of the factors that contribute to an unwanted situation	0	10	35	60	73	4,1
Following systemic design processes	0	15	48	59	57	3,88
Designing and evaluating alternative interventions towards solving a problem	1	10	26	73	69	4,11
Implementing and assessing the effectiveness of a solution	1	6	24	74	77	4,21
Working with limited resources	1	12	44	67	50	3,88
Time management	1	11	31	57	81	4,14
Project management	1	3	30	74	71	4,18

Table 6. Summary of questionnaire responses on the importance of future skills in engineering and economics.

7.3.1 Meta cognitive skills and competences

Cognitive skills and competencies are related to the soft skills that help an individual to excel independently of subject area. The following chart demonstrates the summary of questionnaire responses in relation to soft skills.

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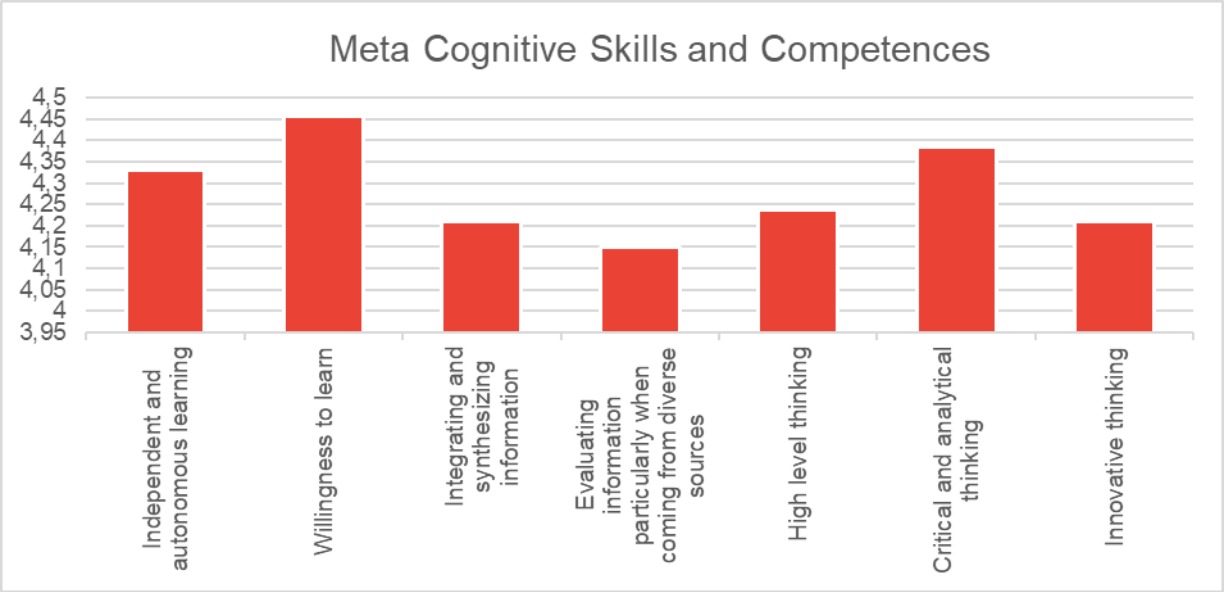

Figure 3. Summary of questionnaire results on cognitive skills and competencies in engineering and economics.

The skills that were most highly rated were “willingness to learn” and “critical and analytical thinking” while the “ability to evaluate information” was rated as the least relevant in this competence group. Other skills include “independent and autonomous learning”, “innovative thinking”, “integrating and synthesizing information”, and “high order thinking”.

7.3.2 Project management skills and competences

Project management skills are related to the ability of an individual to engage others, to communicate effectively, to plan, and prioritize, and to see a project to completion. The following chart demonstrates the summary of questionnaire responses in this competence group.

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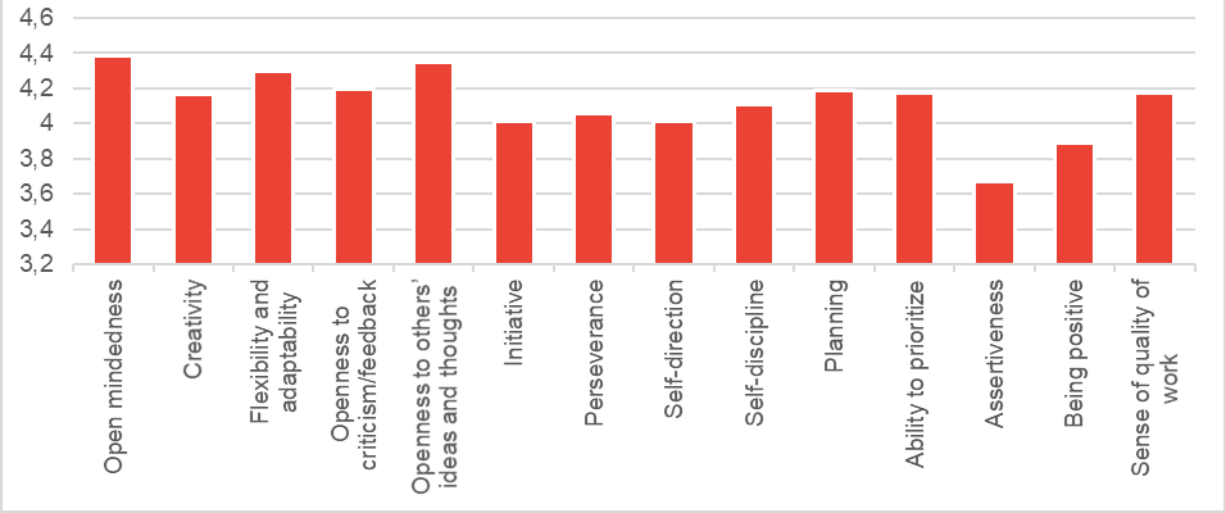

Figure 4. Summary of questionnaire responses on project management skills and competencies in engineering and economics.

The chart demonstrates that all competences in this group are considered important by project participants, with small deviations on their perceived significance. “Open mindedness” and “openness to others’ ideas and thoughts” were deemed as the most relevant while “assertiveness” was considered the least important. Other competencies perceived as desirable include “openness to criticism and feedback”, “flexibility and adaptability”, “sense of quality of work”, “planning”, “ability to prioritize”, and “creativity” while to a slightly lesser degree the competences of “self-discipline”, “perseverance”, “initiative”, “self-direction”, and “being positive” followed.

7.3.3 Interpersonal skills and competences

Interpersonal skills are related to the ability of an individual to collaborate in a group, to communicate effectively, to understand the needs of others, and to transfer knowledge to the real world. The following chart demonstrates the summary of questionnaire responses in this competence group.

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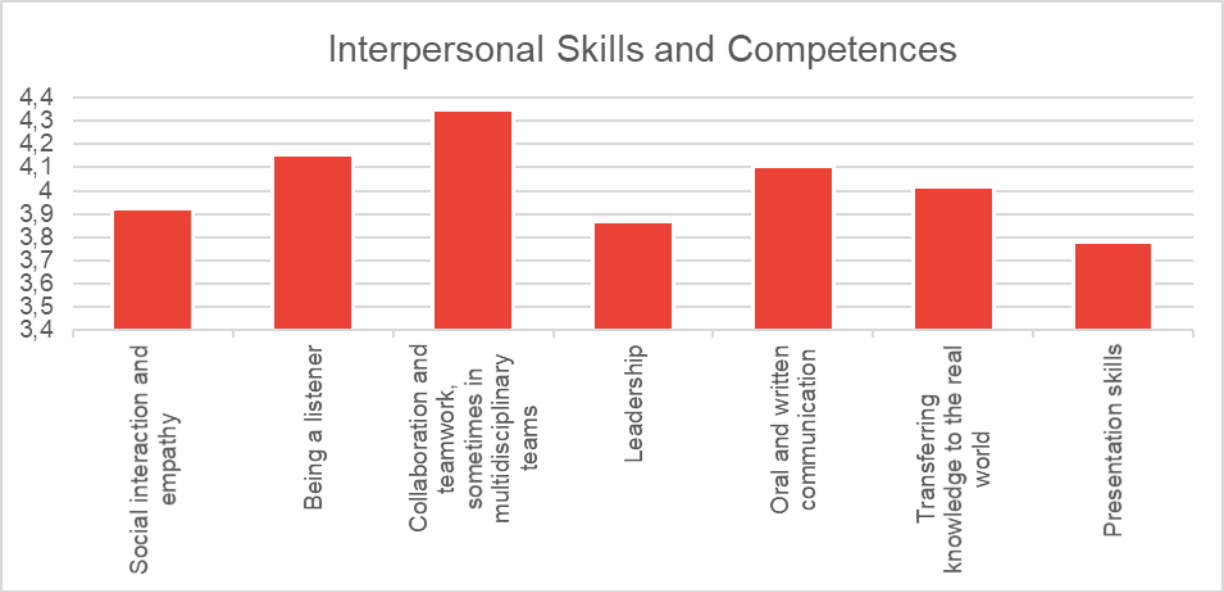

Figure 5. Summary of questionnaire responses on interpersonal skills and competences in engineering and economics.

"Collaboration and teamwork" skills were considered highly important while "presentation skills" were perceived as the least relevant. Additional skills include "being a listener", "oral and written communication", "transferring knowledge to the real world", "social interaction and empathy", and "leadership".

7.3.4 Problem-solving skills and competences

The comparison between the skills in this category can be seen next. The general term "problems-solving skills" was naturally the highest rated as it encompasses all others. Other competencies that were considered important include "providing clarity", "implementing and assessing the effectiveness of a solution", "project management", "time management", "designing and evaluating alternative solutions", and "analysis of the factors that contribute to an unwanted situation". Less significant were considered the competencies of "working with limited resources" and "following a systemic design process".

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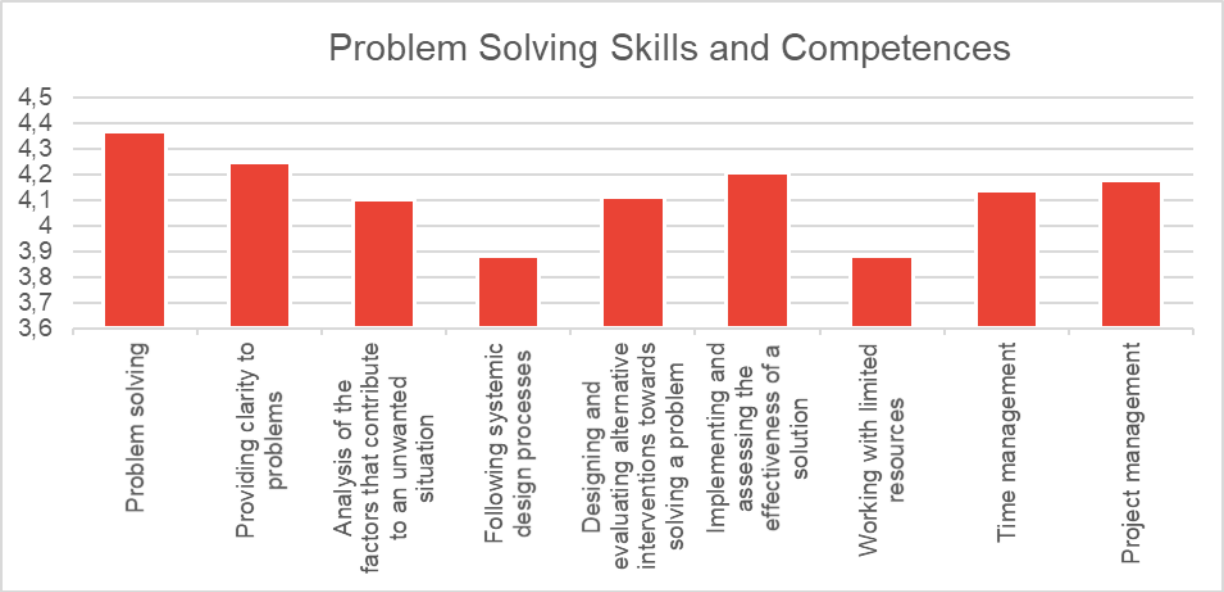

Figure 6. Summary of questionnaire responses on problem solving skills in engineering and economics.

7.5 Importance of pedagogical methods

Students were also asked if they thought that the current educational system allows individuals to develop the skills that they consider to be important in their academic and future professional careers. As the following figure demonstrates, students mostly tended to "no" although the number of undecided students was equally high.

Subsequently, students were asked to indicate which of the emerging pedagogical methodologies they believed were most suitable for developing skills desired by industry. The following table provides a summary of responses on a scale from 1 to 5, with 1 corresponding to "not suited" and 5 to "totally suited".

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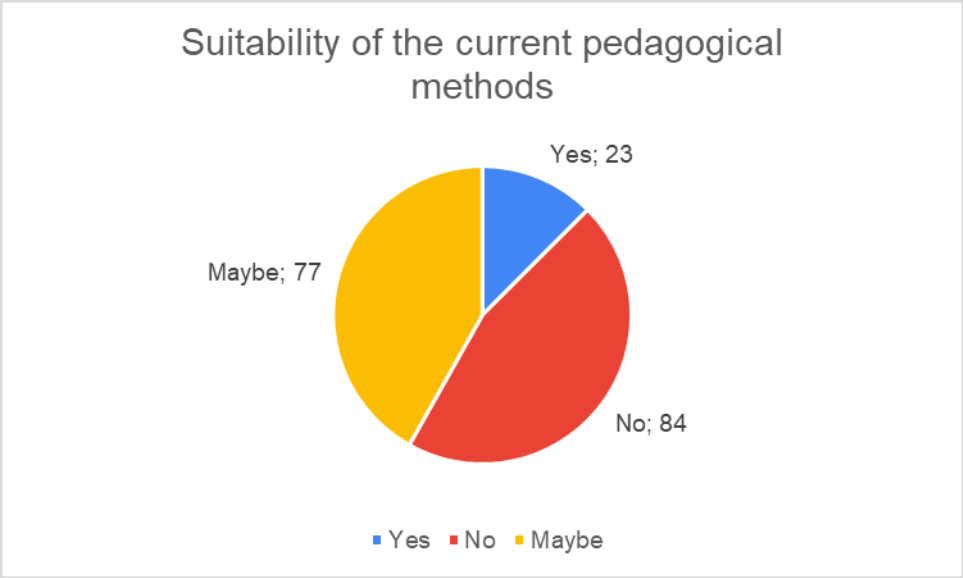

Figure 7. Summary of responses on the suitability of current educational pedagogies in engineering and economics.

	1	**2**	**3**	**4**	**5**	$\overline{X}$
Flipped classroom	10	48	53	38	19	3,04
Problem-based learning	0	3	31	67	69	4,19
Cooperative learning	11	21	49	54	34	3,47
Gamification	22	22	44	50	34	3,30
Design thinking	2	8	44	69	44	3,87
Thinking-based learning	2	8	32	65	62	4,05
Competency-based learning	3	11	48	59	45	3,8

Table 7. Summary of questionnaire responses on emerging pedagogical methodologies suitable for building problem-solving capacity in engineering and economics.

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Specifically, students were asked to consider the following the methodologies of flipped classroom, problem-based learning, cooperative learning, gamification, design thinking, thinking-based learning, and competency-based learning.

According to questionnaire respondents, “problem-based learning” was the most relevant educational approach in engineering and economics, followed by “design thinking”, “thinking-based learning”, “cooperative learning”, and “gamification”. “Flipped classroom” was perceived as the least relevant. Students also provided some qualitative comments on educational design:

- Deploy combinations of the pedagogical methods proposed
- Introduce feedback mechanisms in learning
- Ensure flexibility in assessing student progress
- Change assessment methods as exams favor results over knowledge acquisition

7.6 Summary of findings and identification of higher education challenges in problem-based learning

Based on the above analysis, it becomes apparent that students have a good idea of the skills that they would like to develop. The skills could be categorized as follows:

Skills related to lifelong learning: “independent and autonomous learning”, “willingness to learn”.

Skills related to project management: “planning”, “open-mindedness”, “being open to feedback”, and “implementing and assessing the effectiveness of a solution”.

Skills related to collaboration: “collaboration and teamwork” and “being a listener”.

Skills related to creativity: “creativity and adaptability”, “integrating and synthesizing information”, and “openness to other’s ideas”.

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Skills related to problem-solving: “problem-solving” and “transferring knowledge to the real-world”.

Digital literacy: “digital skills”.

This demonstrates that students have a very good understanding that to address today’s real-life challenges they need to be open-minded, to collaborate in teams, to think critically, and to learn independently throughout their career. It further highlights the importance that students placed on digital literacy.

These findings are further reinforced through responses in subsequent questions, such as on the importance of technical skills, in which again the need for “digital literacy” is highlighted. Similarly, responses on project management skills highlight the need for “open-mindedness” and “being open to feedback”, responses on interpersonal skills highlight the need for “collaboration and teamwork”, responses on meta-cognitive skills bring forward the need for “analytical and critical thinking”, and responses on problem-solving skills highlight the importance of overall “problem-solving” capacity.

Finally, in relation to pedagogical design, responses highlight the fact that students are knowledgeable on emerging pedagogical design and that they consider problem-based learning and thinking-based learning as appropriate for their development.

These findings demonstrate that there is an opportunity and a need in higher education in engineering and economics for introducing emerging problem-based learning design into existing educational practices through activities that promote collaboration, open-mindedness, and creativity. They further highlight the perceived benefits of digital technology among students. The HERA project aims to introduce a solution that addresses these needs through a digital learning application that promotes problem-solving capacity through collaboration and creativity in a manner that simulates the function of multidisciplinary teams in the real-world.

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8. HERA problem-based learning requirements for students

Engineering and economics higher education programs both develop students to be problem solvers. Engineering students aim to introduce innovative solutions to real-world problems. This objective must be reached within specific resources and timelines. In this context, engineering and economics are complementary principles the combination of which can contribute to the design of viable, sustainable strategies for addressing the challenges of the 21st century.

HERA designs a problem-based learning approach for engineering and economics principles that encourages students to combine knowledge from diverse thematic areas towards designing out-of-the-box services and products that address business and societal needs. In the context of HERA, students are exposed through game-based approaches to real-world inspired educational activities. The activities are complex and require the students to identify the parameters of a given problem, to break it down to smaller challenges, solve those, and synthesize the solutions to the smaller tasks into one for the overall activity.

This section documents and analyses the learning needs of students in alignment with industry needs, that is, it establishes what students expect or desire from their education to become well-functioning and effective professionals. Namely, it includes needs related to core knowledge, employability, mobility, lifelong professional development, etc. The section focuses on competences and skills that students need to build for effectively transitioning into the work environment. Earlier sections of this report documented a long list of desirable competences. This section analyses in more depth the competencies on which the HERA project mostly focuses and discusses how problem-based learning promotes their development in a manner that allows their deployment in real world contexts.

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8.1 Exposure to industrial and entrepreneurial processes

One of the key objectives of higher education is to build skills demanded by industry and to link curricula and educational activities to professional practices, helping to bridge the skills gap between the worlds of academia and work. Establishing links with industry involves both technical and practical knowledge as well as exposure to entrepreneurial processes.

The HERA learning intervention that aims to deploy game-based simulations of the real-world will contribute to the exposure of higher education students to industrial and entrepreneurial practices early on, while they are still enrolled in academic programs. This exposure will prepare students to become effective professionals once their transition to the world of work.

Industry and business are constantly evolving, requiring continuous updates of diverse qualifications. The complex learning scenarios that are foreseen in the HERA learning intervention ensure that students will develop rich skill sets that touch upon both engineering and economics principles.

The HERA learning intervention is based on active, experiential methodologies (Prince, 2004, Leal-Rodriguez & Albort-Morant, 2019) that engage students in hands-on activities inspired by real-world practices. Through learning games, students will build theoretical knowledge and practical skills early on in a manner that allows them to apply the new capabilities in real-world situations.

8.2 Analytical and critical thinking skills

Analytical thinking is observing and researching a problem or topic to develop a thorough understanding of the task at hand and potential solutions to it (Analytical Skills, 2020). Analytical skills are important because they allow students to find solutions to common problems and make decisions about what actions to take next. Understanding problems and analyzing situations for designing viable solutions is a key skill in every position at every

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level. Developing this ability can improve an individual's work, help achieve company goals, and eventually support personal career growth goals.

Critical thinking refers to the ability to analyze information objectively and make a reasoned judgment (Doyle, 2019). It involves the evaluation of sources, such as data, facts, observable phenomena, and research findings. Good critical thinkers can draw reasonable conclusions from a set of information and discriminate between useful and less useful details to solve problems or make decisions.

Analytical thinking, critical thinking, and informed decision making that is the result of analytical thinking processes are important assets for students in their academic and their future professional careers. The HERA serious game will contribute to the development of analytical and critical capacity by exposing students to real-life problems the solution to which requires breaking down a problem for understanding its parameters, researching information, evaluating information, and synthesizing informed solutions. In their engagement with the HERA serious game higher education students will be exposed to rich scenarios with diverse requirements. In synthesizing a solution to each activity, students will be challenged to make decisions in the context of problem-solving processes. Students will further be called to evaluate their decisions, ensuring that these address the needs of end users of a specific solutions building in analytical and critical thinking skills in the process.

8.3 Adaptability

Flexibility is an important social skill. Flexibility enables individuals to build good relationships, collaborate effectively, and solve problems or try new approaches towards achieving their goals. Flexible thinking allows the design of multiple approaches towards solving to a given problem (Cook, 2018). Through flexible thinking, students can consider diverse points of view and introduce a wealth of potential solutions. Flexible thinking fosters the development of resilience among students and builds their self-confidence in addressing

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emerging, unknown, and complex problems. Students understand that nothing is predictable in a workplace. As a result, they must be flexible and adaptable and always find a way to overcome obstacles and move on. Students should understand that thinking positive is the best way to success and try to embrace the changes.

In HERA scenarios students will be exposed to complex issues, in which requirements may evolve. Through the learning scenarios students will understand the concept of evolving requirements in the real world, which may be the result of a fluid business environment and may emerge because of continuous collaboration with customers. Students will learn to prioritize requirements, to organize work tasks for the requirements to be accomplished, and to update requirements if this is dictated by an evolving customer situation.

8.4 Problem-solving and assessing the effectiveness of a solution

Problem-solving skills are competencies that allow individuals to enrich their learning and critical thinking (Medicott, 2019). Problem-solving involves analyzing and evaluating complex information, categorizing, establish connections, troubleshooting for solutions, understanding concepts, seeing the big picture, brainstorming, evaluating information, synthesizing ideas, and creating new knowledge from old.

Problem-solving skills development highlights the diverse ways of learning. These skills go beyond basic memorizing and understanding of information and related to higher cognitive processing. Problem-solving skills help students think and not just memorize information. It improves their cognitive ability. Bloom's taxonomy orders the level of a student's capacity to utilize new knowledge as follows from the lowest to the highest level:

- **Level 0, knowledge:** the capacity to remember previously learned information
- **Level 1, comprehension:** the capacity to understand the meaning of new material
- **Level 2, application:** the ability to apply, construct, demonstrate, operate, produce, and use new information

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- **Level 3, analysis:** the ability to analyze, compare, contrast, and differentiate information
- **Level 4, synthesis:** the ability to formulate new structures from existing knowledge
- **Level 5, evaluation:** the ability to judge the value of material

Problem-solving skills are related to stages 3 and up, in which a user can apply, analyze, synthesize, and evaluate knowledge.

HERA builds problem-solving skills through an active learning approach that engages students hands-on in practical activities in a virtual environment. Through well-selected scenarios students will not only understand facts about the given problem but will be challenged to synthesize collaboratively viable solutions, explain the solutions to others, and evaluate their effectiveness. Learning through experience, and more specifically through virtual experimentation, will enable users to be able to use new knowledge beyond the classroom. They will also be able to understand why the information they learn is useful and helpful in their lives. As a result, students will not only build an appreciation for the real-life applications of new knowledge, but they will also be more motivated to learn.

8.5 Creativity and open-mindedness

Creative thinking means addressing something from a new perspective. It is the very definition of thinking out of the box (Doyle, 2019). Often, creativity in this sense involves lateral thinking: the ability to perceive patterns that are not obvious and the ability to come up with alternative solutions when the obvious ones do not work. Creative individuals can introduce innovative methods for implementing projects. They are effective problem solvers and meet challenges. Creative thinking can help departments and organizations move in more productive directions.

Brainstorming introduces a free, open, and inclusive environment that encourages everyone to contribute ideas. In problem solving, brainstorming brings team members' diverse

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experience into play. Participants are encouraged to contribute helping the team to develop a wealth of alternative solutions. Team members build on the ideas of others contributing to the elaboration of complete solutions. Furthermore, brainstorming is fun and helps team members build strong bonds as they design solutions to problems in a positive, inclusive, engaging, and rewarding environment.

In the HERA learning environment students will face challenging issues and, after combining the necessary information, will ideate in an inclusive and encouraging environment on potential solutions without being judged on their ideas. This process will foster positive attitudes on brainstorming as a way of collaboratively tackling problems. Creative thinking and brainstorming are key qualifications in entrepreneurship. Recognizing the importance of creative thinking in engineering and economics, the HERA serious game will introduce a digital, collaborative environment that fosters innovative mindsets.

8.6 Integrating knowledge from diverse thematic areas

Tackling real-life problems requires the integration of knowledge from diverse fields. The ability to identify, analyze, and combine relative information from rich sources is significant for addressing real-world issues (Ackerman & Perkins, 1989).

This need for integrating a wealth of knowledge in problem solving contexts is well understood in tertiary education. It has led to the design of interdisciplinary curricula that provide students the opportunity synthesize knowledge from diverse subjects. While interdisciplinary learning introduces an overreaching topic, theme, or problem that shapes the learning experience it requires integration of knowledge from different disciplines.

HERA will deploy interdisciplinary learning that integrates fundamental and practical knowledge from engineering and economics. In the proposed active learning environment students will face activities that are inspired by complex real-life challenges. Similarly, to

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real-life processes, the solution to the HERA activities will require the integration of diverse knowledge to address non-trivial problems that span subjects, thematic areas, and curricula.

8.7 Undertaking roles in a team, leadership in areas of expertise

In an effective team, each member works to the best of their abilities towards achieving identified targets. In a well-designed team, members are compatible. This helps avoid conflicts and misunderstandings. Effective teams include individuals that assume different roles. The team leader coordinates activities and extracts the best out each team member. The team leader should inspire team members and encourage them to seek advice and guidance whenever required. The team leader should be a role model for his team members. Other team roles include the evaluator, who evaluates different ideas and selects the most appropriate one for addressing team objectives, the implementer, who contributes to project progress, the idea generator, who thinks out of the box towards introducing a solution, the finisher, who takes a draft and turns it into a finished product, and more (Belbin, 2021).

A team member must clearly understand fellow team member perspectives. Each team member should be very clear about their role and responsibilities in the team. It is the duty of the team leader to delegate responsibilities as per the interest and specializations of the team members without imposing tasks on them.

Leadership skills are essential in the 21st century. They include communication capacity, active listening, motivation, giving and accepting feedback, a feeling of being able to solve problems, positivity, accountability, creativity, commitment, and other properties. All the above are fostered by the HERA learning intervention, which focuses on team effort, the exploitation of diverse skills in a team, brainstorming, evaluation, and positive feedback for solving challenges on societal and industry issues.

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8.8 Collaboration and teamwork

Teamwork is the collective effort of each team member to achieve their assigned goal. No member can afford to sit back and expect the others to perform on their behalf. Team members must be committed to their team as well as their organization to avoid conflicts (Watkins, 2018). Nothing productive comes out of unnecessary conflict, which in turn diverts the concentration and focus of team members. Every member should adopt an adjusting and a flexible attitude. One should consider their team members as a part of their extended family all working together towards a common goal. Team members rely and dependent on each other for producing the best outcomes. Working in teams enables professionals to be quicker and more effective in their work as compared to people who work on projects on their own. Collaborating also makes team members more responsible, which goes a long way in raising their motivation levels especially when teams work virtually.

Industry and business are sectors where most tasks require efficient teamwork. This is the result of complex requirements that cannot be addressed by one individual. Scholars learn the importance of being open-minded and understanding to others' ideas and opinions. The HERA serious game promotes collaborative learning. Through the different scenarios students will communicate with each other on the current status of a jointly owned project, they will brainstorm, and they will integrate new knowledge though cooperation for achieving optimal results.

The HERA learning environment will be designed around real-life scenarios the solution to which requires the combination of knowledge from diverse fields. For producing the best results students will collaborate and will combine complementary knowledge and skills in solution design, understanding the importance of collaboration in the world of work.

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8.9 Effective communication and open-mindedness

The constant evolution of business challenges teams to adapt to change. Effective communication and efficient information sharing enables team members to stay up to date as new data emerges. It allows team members to be well informed of any changes in time for introducing necessary adjustments. Efficient communication systems allow the effective exchange of ideas among individuals with diverse backgrounds and cultures. This creates understanding among teammates for the greater good.

Effective communication requires open-mindedness to the ideas of others. It further requires that individuals are open to constructive criticism in a positive environment in which a team works towards a common goal. Diversity is turned into an advantage through mutual understanding that facilitates progress. Eventually, entire professional networks benefit from synergies.

Effective communication is a factor that determines how well a team collaborates and affects team performance towards reaching goals. It is significant for building an inclusive team environment and encouraging each team member to contribute to their best ability. The success of any project team relies on effective communication and collaboration. In the HERA serious game learning environment team members will communicate with each other with ease, share their project goals, and prioritize the tasks under implementation.

8.10 Presentation skills

Presentation skills can be defined as a set of abilities that enable an individual to interact with the audience, transmit the messages with clarity, engage the audience in the presentation, and interpret and understand the mindsets of the listeners. Effective presentation skills are a part of every communication. Students need effective presentation skills to present their ideas, projects, plans, strategies, and products in front of their team members, as well as the stakeholders. Presentations may take place in oral or written form

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and is an essential part of collaboration. Students need to be able to effectively convey complex and structured ideas in academic, scientific, social, or business contexts. Presentation skills are essential in communication, leadership, and teamwork (Zivkovic, 2014).

Through HERA learning intervention, students will build presentation capacity through activities that encourage them to communicate their ideas towards solving complex challenges to team members and others. This practice will empower them to build their capacity to present facts, data, and analyses in their future workplace and in business.

8.11 Planning

Project management is the practice of applying knowledge, competence, services, and methodologies towards bring a project to completion according to the needs and requirements of end users. Project management involves understanding the problem parameters, developing an implementation a plan, and executing this plan for completing the project.

Time management is the management of the time invested and the progress made towards the completion of project activities. Effective time management requires planning, scheduling, monitoring, and controlling project activities (Donnely, 2019). It further requires identifying and observing of dependencies among implementation tasks and adjusting when the completion of tasks drops out of schedule.

Planning is key in project management. While many project planning methods exist, a simple one is to make a list in advance of all the tasks and activities that need to be implemented. The next step is to prioritize tasks, identify which of them take less time or which are important and urgent, and finally estimate the time that each task requires for being completed.

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While playing the HERA serious game, the students will understand the importance of organizing and planning the time spent on each task of a scenario. The result of their good time management will be the increased effectiveness and productivity.

8.12 Prioritizing

Breaking down a problem into smaller tasks and prioritizing their implementation is an important skill in problem solving and project management processes (Adler, 2018). Effective prioritization is essential to the success of a project and the engagement of the implementation team. Prioritization involves identifying desirable features of a product or service under design and the order in which these should be delivered to the customer. Decisions consider customer needs, how essential individual features are, and the conveying of a sense of progress through incremental delivery to both the implementation team and the users. Emerging methodologies on design, such as agile that allows teams to prioritize objectives as project implementation requirements evolve, can significantly help the prioritization of task implementation in complex problems. Agile design has originated in software engineering but has wide applicability in all engineering sectors (Edeki, 2015).

Through HERA, students will learn effective ways to prioritize tasks to increase their productivity. When deciding which tasks require immediate attention students will practice focusing on the consequences of not completing a particular task. They will be encouraged to consider the most detrimental effects if a task is not completed in time to the overall implementation progress considering that even a task with an extended deadline for completion can sometimes be put on hold while completing a job with an immediate deadline.

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8.13 Working with limited resources

Project management and implementation always involves working within limited resources. To effectively simulate the real-world problem-based learning practices must integrate resource management as a tangent in project implementation. For example, they should challenge students to work with a limited budget, limited natural resources, limited technology, limited time, and more.

The HERA learning intervention will include building skills for effective resource management, including time management. Students will focus on engineering and economics principles in a realistic and pragmatic manner considering technology and viable implementation budgets. Students will be encouraged to identify resource limitations, to recognize that business cannot always be conducted "as usual" when resources are constrained, and to design implementation plans within the identified limits. In addition, students may need to adjust plans, requirements, and deliverables to ensure that priorities can still be met even in the face of one or more limiting conditions.

8.14 Willingness to learn and autonomous learning

Willingness to learn (Shi et. al, 2018) is a significant factor for self-motivation in learning. It can make students more autonomous in the learning process and can influence positively their performance. In innovation related sectors, such as engineering and economics, willingness to learn is important as technology and processes are expected to continue to evolve in the coming decades spanning the careers of young professionals.

Willingness to learn can also be positively affected by virtual learning environments (Shi et. al, 2018). In a virtual learning environment students feel safe and act as if they play a game, without the risk of underachievement. In this way, students feel free to experiment while learning new things.

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HERA will encourage students to develop self-confidence and understand the importance of this safe environment that virtual reality provides. Students will understand that in their future careers they will face many difficulties. This helps them build maturity and prepare for addressing emerging issues.

8.15 Transferring knowledge to the real-world

Transitioning from the academic environment to the real-world and being able to use knowledge developed through educational curricula in real-life situations is a key objective of tertiary education today (European Commission, Transferability of Knowledge across Economic Sectors, 2013). Building knowledge in a manner that enables students to apply it for solving real-world problems contributes to addressing the skills gaps between academia and industry. University curricula should not only build knowledge and skills that are in high demand in the professional world, but they should do so in a manner that allows students to deploy this knowledge effectively once they transition into the work environment.

Students that will use the HERA game-based learning environment are more likely to develop significant skills that will equip them effectively transition to their future workplace environment. This will be achieved by exposing students to scenarios inspired by real-life. The HERA serious game will simulate the workplace environment. The activities in the learning scenarios will be realistic. Their solution will require analysis of information, combination of knowledge, collaboration, synthesis, and evaluation skills. Scenarios will further encourage creativity and entrepreneurial thinking for introducing out-of-the-box solutions. Engaging in the HERA learning activities will expose students to real-world challenges and practices in industry, demonstrating how new knowledge is applied in practical situations in problem-solving contexts.

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8.16 Digital skills

Digital skills are considered as part of transversal competencies that help an individual excel independent of subject area. All jobs today require digital skills to some degree. The Digital Agenda for Europe (European Commission, Digital Agenda for Europe, 2010) highlights the need to develop digital skills for work and everyday life, bridging the digital divide (European Commission, A Digital Europe Needs Digital Skills, 2021). Digital skills involve a wide array of competences, from the ability to use digital tools and services for work, for business and personal transactions such as paying bills, requesting government-issued documents and certificates, and more, understanding of the concept of digital footprint, namely an individual's information published on the internet, understanding safety issues, and more. In innovation related sectors, the deployment of digital tools is the norm (Iordache et. al, 2017).

HERA will contribute to the development of digital skills through the design and implementation of a digital game specifically built for learning purposes. The game will be openly available to interested parties, contributing to the availability of quality digital content for educational purposes. Through the HERA tool learners will have opportunity to design solutions and to collaborate with peers on-line, enjoying the advantages of digital technology which include immediate feedback and high interaction that promotes engagement.

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9. HERA problem-based learning requirements for educators

HERA aims to introduce new teaching methodologies into higher education for promoting the development of problem-solving skills in multidisciplinary contexts. Teachers and instructors play an important role in the adoption of emerging, innovative pedagogical practices. To effectively support game adoption in education, stakeholders need to understand teachers' current teaching practices, challenges, and needs (Mathe, Verhagen, Wiklund, 2019). This section documents the needs of educators in terms of building their capacity to apply emerging pedagogical approaches in their instructional practices for developing desirable skills for their students in relation to industry needs. It further focuses on what educators need to effectively deploy IT as a learning tool in broad instructional activities. Earlier sections of this report documented a long list of desirable competences for students. This section analyses in more depth the competencies on which the HERA project mostly focuses from the instructor point of view.

9.1 Applying interdisciplinary methodologies that integrate IT

Interdisciplinarity in teaching is a priority because each student has individual traits, interests, and background. To most effectively reach each individual student an educator needs to address his or her interests. IT is deployed widely in interdisciplinary programs such as digital humanities, language technologies, and integrated natural sciences that combine IT with engineering, economics, or social sciences. IT is nowadays relevant to all thematic areas in learning. Integrating IT in interdisciplinary programs is important for bringing education to the digital age and for making it relevant to industry needs. Researchers suggest that a good way to integrate IT into interdisciplinary programs is to pay particular attention to the transnational and intercultural context (J. Babic, I. Lovrek, V. Podobnik and F. P. Foix, 2019).

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For example, to develop a program for financial managers, designers need to understand the basic principles of accounting. To work as a software engineer in the ministry of agriculture, a professional must understand the basics of agricultural engineering. These examples demonstrate that it is crucial that novel teaching methods incorporate interdisciplinarity. Educators need to understand the links between their area of study and broader life, social, and business goals and to foster critical mindsets that allow them to effectively work in a complex work where solutions require the integration of knowledge from diverse fields.

9.2 Promoting the transferability of knowledge

Engineering educational organizations face new challenges on effectively building the appropriate skills among future engineering professionals considering market demands. One of the objectives of higher education is to ensure that newly developed skills are transferable to the real world. Active learning design is one of the emerging approaches that allow students to transfer newly developed knowledge to the real world (Llorens, Berbegal-Mirabent, Llinàs-Audet, 2017). Active learning is integrated in teaching and learning of diverse subjects. It is applied more in practical subjects such as robotics or programming individually or in pairs and is followed by assessment of learning results. It is less used in the development of theoretical knowledge. Active learning is, thus, relevant in disciplines such as engineering and economics both of which challenge students to introduce practical and workable solutions to actual challenges. Educators need to be able to deploy emerging active learning design in various forms, including hands-on activities, deployment of digital exploration tools, collaborative activities, visits to sites of interest, role-playing, or combinations of the above that challenge learners to develop knowledge in a way that simulates its application in real-life contexts.

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9.3 Developing the problem-solvers of tomorrow

Problem-based learning is one of the active learning approaches that help students build the foundational knowledge and transversal skills that will allow them to become the problem-solvers of tomorrow. It is often combined with other active methods listed above. For example, after lecturing on a new topic the teacher may assign an open-ended problem for the students to discuss and research the web for possible solutions. After exploring possible implementation approaches students combine ideas to synthesize a new solution. Educators need to develop their capacity to be mentors and facilitators in problem-based learning, which is heavily student centered. They need to provide inspiration, to foster class collaboration, to answer questions, to provide direction, and to support students in the construction of new knowledge (Duch et. al, 2001).

9.4 Promoting learner engagement

Gamification offers significant advantages to learning when properly designed in correlation to educational objectives (Garris et. al, 2001). It refers to the deployment of game elements in non-game contexts, such as education (Michael & Chen, 2006). It offers significant advantages in learner engagement in the educational process through clear and interesting missions, collaborative settings, and real-time feedback that helps students understand the consequences of their choices. Gamification is used less often than other emerging educational approaches, such as active and problem-based learning. Gamification may be deployed, for example, a couple of times during an academic semester when a good game that is well-linked to educational objectives is available. Designing an effective learning game is not a trivial process. More can be done for development educational content in the form of learning games (European Commission, Digital Agenda for Europe, 2010). Good games are needed and welcomed for incorporation in teaching.

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On the other hand, the method of creating a game is used increasingly more often as an educational activity itself. Some teachers use gamification, for example telling the students to sort themselves according to some algorithm, writing their names on the board, or guessing a number according to a sorting tree. Kahoot® and other similar quiz applications are used frequently instead of slides.

Educators have a lot to gain from integrating gamification into their educational practices. Building their competences on deploying games in learning helps educators to spark interest among their students on challenging topics, help students develop practical skills, foster motivation, integrate digital tools into learning, exploit immediate feedback in educational contexts, foster the development of soft skills, such as collaboration and critical thinking, and more.

9.5 Fostering collaboration

Group-work is often deployed in educational contexts in different ways. The most popular approach is to encourage students to discuss ideas with their desk mate. Paired programming is sometimes deployed as well, but it does not always have the desired results as it is dependent on the personality characteristics of students. Forming groups is especially useful when students do not know each other well, follow different fields of study, or have complementary skills (Belbin Team Roles, 2021). It allows students to become acquainted. Once students become familiar with each other they can form groups on their own as they already know with whom they can work well together.

Building collaboration skills among students is particularly important as in the real-world problems are solved by teams and not individuals. This is particularly the case for introducing solutions to complex challenges of the 21st century. Educators, therefore, need to build their capacity to promote classroom collaboration for the benefit of their students.

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9.6 Promoting student capacity to work on projects

Qualitative research (Llorens, Berbegal-Mirabent, Llinàs-Audet, 2017) suggests that a combination of project-based learning, namely learning based on larger projects that offer depth and are implemented of lengthier periods, and the learning contract is sufficient to ensure a satisfactory skills level for the profile of engineers. Project-based learning is very common and applied in several courses. Sometimes projects span an entire course or several courses in the curriculum. Project activities may be challenging for students, as finding the time to meet with several groups on diverse topics is not a trivial task. Educators can benefit from developing their capacity to coordinate, guide, mentor, and facilitate students in the context of non-trivial project activities that simulate real-world work environments and prepare students to transfer from the academic environment to the professional world.

9.7 Fostering green and sustainable mindsets in engineering and economics

Throughout their lifecycle IT products and services are associated with significant levels of energy consumption and carbon emissions. On the other hand, despite being one of the main contributors to global carbon emissions, the IT sector has a crucial role to play in boosting productivity and sustainability in many sectors, such as education, transport, agriculture, business, buildings, health, power, and manufacturing (Kariuki, 2021). Sustainability is not yet a common theme in learning but as it becomes more and more important teachers feel the need to introduce the topic to their students. For instance, in programming courses some of the platforms used have limited volume, which challenges students to think on how to keep their code as light as possible and try to reuse code as much as possible. The best sustainability effect is when students can reuse or apply their knowledge acquired from school to their work or private life. Educators can benefit from building their capacity to promote emerging green skills among their students by deploying emerging learning design, such as active and problem-based learning.

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9.8 Fostering the development of soft skills

Other skills that teachers strive to build among their students, and thus need to also develop themselves include:

- Critical thinking
- Finding relevant information
- Ability to notice mistakes
- Knowing how to study
- Entrepreneurial skills
- Group-work
- Leadership
- Communication skills
- Perseverance
- Peer-to-peer learning
- Information acquiring
- Functional reading
- Systemic or algorithmic thinking
- Computational and analytical thinking
- Ability to work independently
- Transferable skills
- The courage to ask for help

Although the needs of industry are versatile these skills are applicable in industry as well. They constitute basic or social skills that are needed everywhere. When teachers ask industry professionals about their needs, they get very different answers. Mostly, professionals mention the same basic skills and then more specific skills fitting a specific position. Some students may perform well in class but fail to deliver what the industry needs and vice versa. Although it is hard to match the versatile needs of industry, the feedback

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from industry has been positive so far. Industry stakeholders expect that the skills built in the university are relevant to their needs. Consequently, educators need to develop their capacity to promote these soft skills desired by industry among their students.

9.9 Other good practices

Other good practices that are considered effective and may be positive for educators include mocking or copying, using examples, and accommodating these needs. Leveling, for example delivering each assignment 3 times, with each deliverable being more in depth than the previous one, raises the interest of both novice and experienced students. These approaches may be valuable options in an educator's toolset.

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10. The HERA game-based learning framework for building problem-solving skills for the 21st century

This section uses the above analysis to introduce an active learning intervention for building problem-solving capacity among engineering and economics higher education students. The proposed learning framework is the basis for the design and implementation of the HERA serious game that encourages students to address non-trivial challenges of today by integrating knowledge from diverse thematic areas, thinking critically, and collaborating in multidisciplinary teams in a manner that simulates real-world industry practices. Thus, the proposed learning intervention prepares students for their professional roles after graduation and facilitates the transferability of newly developed knowledge from the academic environment to the world of work.

10.1 Methodology

HERA aims to develop higher education 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 (United Nations Sustainability Goals, 2021). The need to introduce solutions to such emerging societal challenges has further changed the way industry works, pointing to the

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need for integrated, potentially cross-sectoral approaches to solutions of complex problems (European Commission, Modernization of Higher Education, 2014). In this light, higher education must be re-thought and re-engineered 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. Higher education 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 (Cimatti, 2016). 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 that active learning increases the performance of students in science, engineering, and mathematics (Freeman et. al 2014). HERA aims to design an active learning framework for higher education 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 problem-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 higher 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 higher education can be further linked to the needs of the world of work through virtual educational services that help students become immersed into

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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. In problem-based learning students are exposed to complex, real-world problems are used as the vehicle to promote student learning of concepts and principles as opposed to direct presentation of facts and concepts (Duch et. al, 2001). HERA introduces a serious game-based learning environment that aims to build problem-solving skills among engineering and economics students. The HERA learning intervention challenges students to synthesize knowledge and apply it to new situations. Students are faced with contextualized, structured problems and are asked to investigate and discover meaningful solutions. Through problem-based learning, students will not only strengthen their teamwork, communication, and research skills, but they will also sharpen their critical thinking and problem-solving abilities essential for life-long learning.

By working with problem-based learning, students will become engaged with open-ended situations that assimilate the world of work and participate in groups to pinpoint what is known/ not known and the methods of finding information to help solve a given challenge. Students will have the opportunity to investigate a problem inspired by real life. Students will be encouraged to think critically and brainstorm collaboratively for designing innovative and viable solutions to complex challenges. Finally, students will be encouraged to analyze a given situation and to determine whether a given problem is contained or depends on the solution of additional challenges.

The HERA game-based learning intervention, in which games simulate real-world processes, will enable students to become actively engaged with problem-solving activities in a manner that approaches related practices in the professional world. Students will build practical experience on deploying problem-based learning, going beyond the theoretical study of the methodology. This will allow students to effectively transfer the newly developed skills in

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real-world processes, bridging the gap between higher education and the needs of industry. Students will apply problem solving processes to address difficult situations in diverse sectors, such as computer science, management, economics, and entrepreneurship, and fulfill specific workplace tasks.

The proposed services will 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. Serious games are games that have been developed for a purpose other than entertainment (Michael & Chen, 2006). The advantages of serious games are many (Abt, 1970):

- They expose students to puzzles, and everyone likes to solve a puzzle
- They provide real-time feedback that helps students link the cause and effect of their actions
- They include elements of fantasy that drives student motivation to engage in learning
- They help effectively convey concepts and data
- They allow students to undertake realistic roles
- They create dynamic presentations of real-world situations
- They are suitable for all ages

Serious games are not a new idea. The idea of using digital games in learning emerged when digital games emerged in 1970. The size of the digital games industry is rapidly growing and, according to some analyses, is expected to grow from $129b in 2019 to $436b in 2027 (ReportCrux, 2020). The size of the digital games market for educational purposes, however, is significantly smaller and reaches approximately $2.4b (Research and Markets, 2019). This implies that there is a lot of room for improvement in deployment serious games in learning contexts.

While serious games offer significant advantages in learning, there is also some concern on their efficacy primarily related to whether students make conscious or random choices while

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playing a game. Random choices would not promote learning. To avoid this challenge, researchers have suggested using serious games in broader learning cycles that include presentations, gameplay, and debriefing sessions in which the educator aims to assess the knowledge developed (Garris, 2002).

HERA aims to deploy serious games as a learning tool for building both foundational knowledge and soft skills. The proposed services will 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 further aims to 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.

10.2 Innovation

The innovation of the proposed learning intervention is a combination of:

- The high-level objectives of re-engineering higher education in the multidisciplinary of engineering and economics for building innovation related skills needed for the 21st century
- 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 higher education offerings, the work studies the current higher education 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

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challenges the solution to which stems from exploiting knowledge, technology, and emerging business processes in engineering and economics. The nature of 21st century 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 problem-based approaches that offer advantages in engineering and economics education. Problem-based learning addresses well higher education objectives of building knowledge that students can deploy in the real-world by exposing students to educational scenarios inspired by industry and society. Problem-Based learning combined with game-based educational interventions can further reinforce problem-solving capacity 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 (McGonical, 2010 and 2011).

The HERA methodological framework is reinforced through technical solutions based on IT that facilitates the underlying problem-based 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

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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 (Hauge et. al, 2015). 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.

10.3 Early design

A serious game is being designed and developed with the objective of exposing higher 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.

The design of the game is based on two pillars:

- Designing fundamental functionality that allows solution design in open problems. This functionality will be deployed in all educational scenarios within the game engine
- Designing learning scenarios that will be integrated into the game and will challenge students to tackle non-trivial problems inspired by real world needs

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10.3.1 Game characteristics

The game aims to enrich student experiences on problem-based learning. At the same time, the game aims to provide educators with a platform for designing educational activities and managing the educational process.

Characteristics that target students:

The game has a STEM focus that challenges student to think analytically and creatively for introducing solutions.

The game is a city manager application. Students address scenarios related to improving quality of life in a town. A city manager game provides broad, open opportunities for combining engineering and economics knowledge for introducing solutions to interesting scenarios.

The game is multi-player. Students will use the game in teams. Each team has a common high-level objective, such as designing festive decorations for a city.

The game is role-based. Roles of team members may include, for example, an economic advisor, an environmental advisor, a traffic planner, an energy production developer, an electoral advisor, etc. The roles of team members are complementary, but may also be conflicting, simulating real life situations. Gameplay is both collaborative and competitive. This means that while all team members work towards the same goal, they may have to compete for common, limited resources. For example, the economic advisor may have as a goal to maximize the city income; the environmental advisor to minimize the city pollution; the traffic planner to invest in public transport services and infrastructures; the energy developer to invest on clean energy production; the electoral advisor to maximize happiness among citizens. In the above example the traffic designer and energy coordinator compete for the same financial resources to implement their projects. Students will need to prioritize objectives and allocate resources to achieve the highest possible combined score. The final

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score of the team may be a combination of income + pollution + happiness. This approach encourages team members to consider alternatives in achieving a common goal. This is a realistic scenario in problem solving. The development of a multiuser game is an ambitious approach. However, it offers educational scenarios in terms of building an effective simulation of collaboration in real world teams.

Characteristics that target educators:

An integrated scenario editor allows teachers to create their own educational scenarios. The editor allows teachers to set their own objectives and to tailor the tool to their teaching. They can define the roles of the players and the objectives. Through the integrated scenario editor, educators may create from scratch activities that address the needs of their students. Each educator has access to a **private content management area**, through which she has access to her courses. In addition, the educator has access to **public courses**. These are courses created by others and marked as “public”; in other words, their creators have made the content open for other educators to re-use, edit, and adapt to their own needs. This functionality of the platform encourages the sharing of content and the creation of a community of educators that share experiences and good practices.

An integrated learning management system allows teachers to use the activities in courses and follow the evolution of students. It further allows teachers to schedule activities and share them activities with fellow teachers.

10.3.2 Linking HERA learning game features to desirable skills

The HERA learning game has been designed to address the development of the desirable skills as these have emerged from student questionnaire responses and documented in Section 8 HERA problem-based learning requirements for students. The following table demonstrates these links.

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Skill	How it is addressed in HERA
Exposure to industrial and entrepreneurial processes	Learning scenarios inspired by real-world practices in engineering and economics
Analytical and critical thinking, problem-solving, and addressing the effectiveness of a solution	Open-ended, complex scenarios to which not a single correct answer exists. Rather students are challenged to think critically to synthesize and optimize potential solutions
Creativity and open-mindedness	Students have rich opportunities to design cities, facilities, residential areas, businesses, services, cultural organizations, health organizations, educational organizations, airports, roads, farms, and a lot more that allows them to be creative in the solutions
Integrating knowledge from diverse thematic areas	Learning scenarios are high level and have a broad scope, which challenges students to integrate knowledge from diverse subjects in the curriculum and apply analytical and critical think to synthesize solutions
Collaboration and teamwork, undertaking roles in a team	Learning scenarios are designed in a way that requires the collaboration of members of a team for synthesizing a solution. No single student has access to all the actions required for solving a scenario. Simulating real-life, the game distributes diverse roles among students who must work together towards achieving a common goal. Students may re-play the game undertaking different roles, building perspective from different viewpoints

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	towards solving a problem
Effective communication, including presentation	To introduce a solution to a given scenario students must communicate, exchange ideas, and build on each other's ideas. The game offers communication functionality in the form of a chat. In addition, it offers a common project board on which students can post ideas and see the ideas of others in real-time. This functionality promotes brainstorming and collective solution design
Planning, prioritizing, and working with limited resources	Students work within a limited budget in a manner that simulates real-life. In addition, the broad scope of the scenarios introduces the need for students to break down their solution to smaller tasks and prioritize those both in terms of timely implementation and of budget allocation. Furthermore, the game introduces a tool for prioritizing tasks in a manner similar to that deployed in agile engineering practices
Willingness to learn and autonomous learning	Learning scenarios can only be addressed when each team member effectively executes the actions related to a specific role. This promotes student autonomy. In addition, the attractiveness of the environment and richness of available functionality is a motivator for student engagement
Adaptability	The open-endedness of the learning scenarios and the limited resources available to students for synthesizing a solution challenge them to be adaptable and to flexibly

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	adjust their designs for achieving their goals similarly to real-life
Transferring knowledge to the real-world	Students are challenged to address practical scenarios inspired by real-life. This helps students understand the connection between academic skills and the world of work. It further allows them to work in a virtual environment that simulates related industry practices. Students build knowledge through projects that are relevant in the real-world, and so are in a better position to transfer newly developed knowledge to the world of work

Table 8. How HERA addresses the development of desirable skills.

10.3.3 Organization of a course

The following figure demonstrates the organization of a course in the HERA environment.

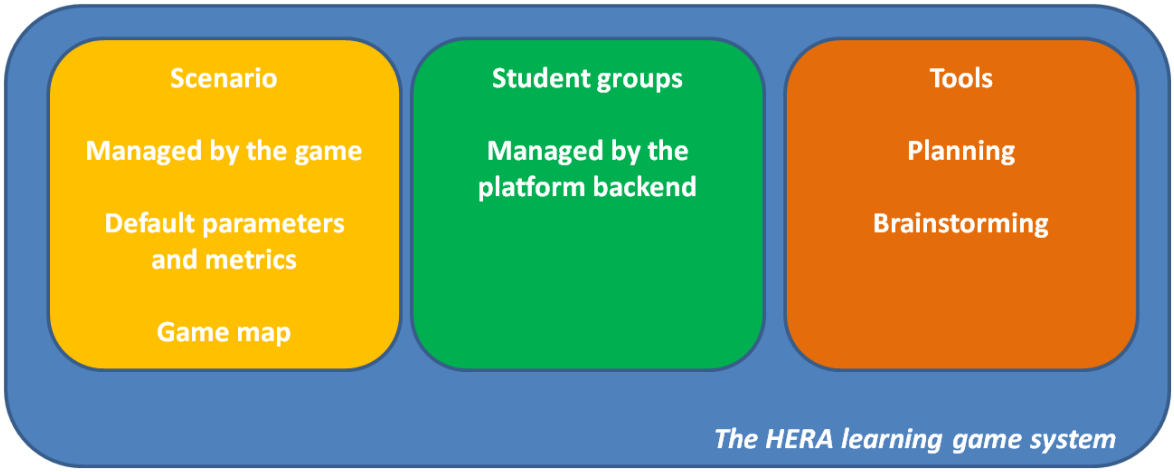

Figure 10. Organization of a course in the HERA platform.

A course is managed by the HERA learning management system. It consists of the following:

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- **A scenario**, which includes some basic parameters and a game map. Default values for the game parameters exist to help teachers that do not wish to customize extensively a scenario
- **A course timeline**, which includes activities that the educator would like to students to engage in a predefined period, for example a few weeks or a semester
- **Student groups**, each of which works on the given scenario. The student groups may be created by the students themselves or by the teacher
- **Brainstorming tools**, through which team members may share and build on each other's ideas
- **Planning tools**, through which team members may break down their project to smaller tasks and prioritize those in terms of timely implementation following agile engineering processes and paradigms (Edeki, 2015)
- **Analytics**, or information on student engagement that can facilitate the educational process and help the teacher provide constructive feedback and monitor student evolution

To engage in a learning scenario, a student must simply register to the related course, assume a role, and continue to gameplay.

10.3.4 Parameters of a learning scenario

A scenario is an activity that challenges students to engage in solving non-trivial problems inspired by today's industry and societal challenges. The HERA learning scenarios are dynamic. In the HERA serious game, a learning scenario is described through the following key characteristics.

- A **map**, on which students will build their solution. The map may be designed by the educator in a manner that addresses the objectives of a given learning scenario. It

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may be fully or partially complete, allowing students to make interventions for reaching the scenario goals

- The **learning objectives**, which are conveyed to students through a set of instructions designed by the teacher
- A description of **student roles**. As stated above, the HERA serious game is collaborative and role based. An educator may define up to 4 different roles that team members may assume. All roles must be adopted by a team member. Team members that have adopted the game roles will work collaboratively towards achieving the game objectives
- A set of **resources for each role**, which the students may use towards addressing the goal of their role as well as the overall goal of the team. These roles are stored in the HERA serious game as variables such as a starting budget, available buildings that the student may use or build, and more
- A set of **actions for each role**, which the students may use for reaching the role objectives in the context of the broader team goals
- **Victory conditions**, in other words the state of the game that corresponds to the completion of the learning activity

10.3.5 A pool of ideas for learning scenarios

Learning scenarios are being selected by engaging students to ensure that the final outcome will address their interests and needs. The scenarios list that appears below has been suggested by students engaged in a brainstorming process. Engaging students from different countries in generating a pool of potential scenarios has significant advantages as it ensures that the HERA serious game will address student interests and expectations.

Some of the scenarios suggested by students include:

- Design and implement festive light decorations for a city

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- 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
- Adjust public buildings so that they are energy efficient
- Develop city infrastructures and services that allow citizens to spend time in both work and leisure
- Control access to beaches and recreational areas in a manner that allows both local inhabitants and visitors to enjoy them
- Organize public parking areas so that all city inhabitants may have access to public buildings
- Design a transportation plan for alternative vehicles in a manner that allows access to all city boroughs while considering safety, interference with other modes of transport, road safety measures, etc.
- Manage immigration with short stay apartments while immigrants are in the process of adapting in their new environment. Organize the distribution of immigrants in the city in a manner that fosters their integration
- Manage the distribution of tourists in a city so that they are presented with alternative activities that alleviate crowds in specific areas and prevents the distortion of life for local inhabitants
- Distribute industrial areas within a city, considering the displacement of workers, the necessary transport for goods, the pollution (atmospheric, auditory, visual), and more

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- Distribute green spaces in a city to achieve a better standard of living considering the relationship between commercial spaces, residential spaces, educational spaces, medical and other centers, and more
- Improve a city's infrastructure to facilitate the development of activities for individuals with reduced mobility. Consider improvements in traffic routes, parking areas, removals of obstacles, planning for street furniture, and more
- Improve water quality and management. Facilitate the use of rainwater both for human consumption and for watering green areas
- Organize the maintenance of a city infrastructure. Avoid concentration of services in some areas in relation to others. Facilitate the transport of individuals in commercial areas
- Study and improve public transport networks in a city considering traffic patterns and the needs of inhabitants
- Organize the control of rats, cockroaches, or other bugs that may in a city
- Organize areas that facilitate activities with pets in a city
- Design infrastructure for the management of storms and hurricanes affecting a city
- Organize services for deterring tax fraud through the monitoring of the standard of living of individuals and their access to municipal resources
- Manage the sewage systems of a city
- Manage the containment of contagious diseases through the establishment of control zones linked to quarantines
- Design remote control of infrastructures in a city
- Plan recycling services. Rewards environmental efficiency. Design a compost center
- Introduce city enhancements that promote urban gardens and agriculture
- Design services that help reduce lighting consumption and associated pollution while ensuring safety

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- Design a network of lifts, escalators, and treadmills in a city that connect buildings, infrastructure, and leisure areas for promoting the quality of life of individuals with disability or reduced mobility
- Organize the effective distribution of hospitals, health centers, day centers, and health infrastructure
- Design infrastructure for deterring terrorist attacks

10.3.6 An example learning scenario: designing festive lights in a city

The scenarios implemented under the HERA learning game have been selected based on student interest and suggestions as described above. This ensures that the scenarios are relevant and address student interests in higher education. The scenarios are complex and require group collaboration to be addressed; no single student can implement a scenario alone. This ensures that students build, in addition to foundational knowledge, soft skills such as collaboration, critical thinking, and problem-solving. In addition, it challenges students to combine information from diverse subjects, to brainstorm, to evaluate their ideas and those of others, to plan and prioritize, all of which are desirable transversal competencies that higher education students need to develop for becoming effective future professionals.

As an example of how the game works, following is the description of an initial scenario that was used to drive the development of the HERA game design, helping anticipate needs and identify implementation challenges. The design of the scenario helps design the gamification aspects of the proposed learning application and provide the basis for the development of additional scenarios. Some early images of the festive 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.

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As with all HERA scenarios, the festive lights activity designed as a multi-player application to be played in teams. Each team member adopts a specific role and has a different view of the game. Each role corresponds to difference objectives, which may be antagonistic to those of other team members. Examples of roles are described in the following table:

Role	Description	Objectives	Available actions
Role 1	Cultural advisor	Maximize tourism	Build/remove culture
Role 2	Treasurer	Maximize the commercial revenue	Build/remove commerce
Role 3	Political advisor	Maximize citizen happiness	Build/remove everything
Role 4	Public Works manager	Manage their budget	Terrain zoning and terraforming

Table 9. Suggested roles for the festive light decorations scenario.

Figure 11. Early screenshots from the HERA digital learning game for developing problem-solving skills among engineering and economics higher education students.

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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, which is to design festive light decorations.

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 consider 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.

10.3.7 Formatting the map terrain

The HERA learning application is a city-builder game. To achieve the objectives of a given scenario students will be allowed to modify the map that is integrated into the scenario description.

HERA offers rich activities to students for customizing their city. This is an important aspect of the game as it promotes learner creativity.

- Students may modify the terrain by adding geographical formations such as mountains, lakes, or plains. This is supported by the **terra-formatting** functionality of the game
- Students may add buildings to an existing town. A rich collection of buildings is available. For more details, please refer to Annex C
- Students initiate their engagement with the HERA learning application by reading the instructions designed by the teacher. The instructions are automatically and transparently integrated into the game through the scenario editor. Students then

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collaborate on understanding the game objectives and synthesizing solutions towards achieving them. The game ends when students have achieved the objectives, i.e., met the victory condition, or they run out of time to complete their implementation

10.3.8 Gameplay

Engaging with HERA starts with the creation of a scenario. The scenario can be created by any individual that has the rights to do so. This is typically performed by the educator. However, as mentioned earlier in this report game design can be an educational activity itself. For this reason, the educator may choose to provide students with the rights to create their own scenarios.

Creating a scenario starts with the design of a base city. Depending on the objectives of the educational activity, the city may be well developed or at the initial stages of design. The latter challenges the students to complete the city building process.

Once the basic city is created, the scenario designer creates the student roles. The designer describes each role and decides on the role's capabilities, namely the way that the student assuming the role will be able to intervene on the city, introducing services or buildings that contribute to the achievement of individual and team roles.

Once the scenario and roles are complete, the educator may create a course on the scenario. The course is the working space in which the students will engage. It has a specific duration and a start and end date.

Students register to the course and join a team. Once they have joined a team, students review the available roles and assume one of those. Then, they collaborate with their team members so that they jointly introduce city enhancements for solving the problem at hand.

During gameplay, students may use a set of tools for communicating on-line, brainstorming, and organizing the implementation of their project. These tools effectively help students

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work in a team, to work in an inclusive and supportive environment, to build on each other's ideas, to organize ideas in pools of related material, to define short and long-term goals, and to prioritize those. All of the above simulate the way teams work in real-life.

The HERA game is open-ended. This implies that there is not a single correct answer to a given problem. This allows students to be creative. It further allows them to replay the game as many times as they wish to optimize their solutions. Students may also present in class the outcomes of their work, triggering collaboration among teams and promoting peer learning.

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11. Conclusions

This document presented the theoretical framework of the HERA project, which aims to build 21st century problem-solving skills among engineering and economics students. The proposed solution takes existing learning practices a step further by deploying on AL, problem-based learning, and gamification principles that are applied in scenarios inspired by the real-world. To reach the proposed design, work focused on existing practices in engineering and economics education. Practices were documented through desk research on past related initiatives as well as a questionnaire-based study that engaged students in Greece, Estonia, Portugal, Spain, and Denmark. The study highlighted the expectations of students in terms of building skills that are in demand by industry, such as collaboration, analysis, project and time management, critical thinking, evaluation of resources, leadership, and more. The HERA solution builds these skills by exposing students to scenarios the solution to which requires combining knowledge that stems from diverse curricula subjects in a manner that simulates how industry works. A multi-user building game is under development in which students assume different roles in city development scenarios implemented through limited resources similarly to related real-life projects.

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Annex A: Template for the description of best practices

TITLE	
[Name that describe this best practice]	
SUMMARY	
[Provide a short description of the best practice being addressed explaining why it was considered a best practice. Max. 10 lines]	
FIELD / DISCIPLINE	[Engineering/Economics/…]
DESCRIPTION	
[What was the initial problem or challenge? Who are the stakeholders involved – people, institutions? When was it implemented? What was the methodological solution/process adopted? Were there any constraints in implementing the best practice? How was the best practice validated? What was the impact – quantitative and qualitative - of the best practice? What were the success factors? How can the best practice be replicated or extended? Are there any resources that can be reused?]	

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REFERENCES AND MORE INFORMATION	
[Is there a contact to get more information for this best practice? Articles or a website?]	
WHY IS THIS PRACTICE SELECTED	[Describe why this constitutes a good practice]
COUNTRIES AFFECTED	[List the countries in which the practice is implemented]
DATE	[Date of this report]
AUTHORS	[Authors of this report]

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Annex B: Student survey questionnaire

Country: _____

Age: _____

Gender: Male / Female

Domain: Engineering / Economics / Other

Indicate the importance of the following skills for your future professional and personal life after you finish your education: (from 1-not important at all to 5-very important)

	1	2	3	4	5
Digital literacy					
Information and media literacy					
Health and wellness literacy					
Formal, basic knowledge in engineering					
Economic and financial literacy, entrepreneurialism					
Ethics					
Global Awareness					
Independent and autonomous learning					
Willingness to learn					

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Integrating and synthesizing information					
Evaluating information particularly when coming from diverse sources					
High level thinking					
Critical and analytical thinking					
Innovative thinking					
Open mindedness					
Creativity					
Flexibility and adaptability					
Openness to criticism/feedback					
Openness to others' ideas and thoughts					
Initiative					
Perseverance					
Self-direction					
Self-discipline					
Planning					
Ability to prioritize					
Assertiveness					
Being positive					

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Sense of quality of work					
Social interaction and empathy					
Being a listener					
Collaboration and teamwork, sometimes in multidisciplinary teams					
Leadership					
Oral and written communication					
Transferring knowledge to the real world					
Presentation skills					
Problem solving					
Providing clarity to problems					
Analysis of the factors that contribute to an unwanted situation					
Following systemic design processes					
Designing and evaluating alternative interventions towards solving a problem					
Implementing and assessing the effectiveness of a solution					

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Working with limited resources					
Time management					
Project management					

Do you think that the current educational system allows you to develop the skills that you consider more important? Yes / No

If not, which of the following pedagogical methodologies would be more suited (from 1-not suitable at all to 5-totally suitable)

	1	2	3	4	5
Flipped Classroom: pedagogical approach in which the traditional elements of the lesson taught by the teacher are reversed – the primary educational materials are studied by the students at home and, then, worked on in the classroom.					
Project/Problem-Based Learning: problem-based learning allows students to acquire key knowledge and skills through the development of projects/solutions that respond to real-life problems.					
Cooperative Learning: The main characteristic is that it is structured based on the formation of groups of 3-6 people, where each member has a specific role and to reach the objectives it is necessary to interact and work in a coordinated manner.					

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Gamification: The integration of game mechanics and dynamics (points, badges, etc.) in non-ludic environments such as education.					
Design Thinking: Design Thinking (DT) applied stems from industrial designers and their method to solve problems and satisfy the needs of their clients. Applied to education, this model makes possible to identify with greater accuracy the individual problems of each student.					
Thinking-Based Learning: This pedagogical approach is meant to show students how to work with the information they receive an to teach them to contextualize, analyze, relate, argue…					
Competency-Based Learning: Instead of focusing only in the acquisition of information, teachers can go through the academic curriculum without significant deviations but focusing it in a different way, putting into practice real examples and, thus, transmitting to their students a more tangible dimension of the lessons.					
Other: _____					

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Annex C: List of available buildings and services supported by the HERA game for city formation

Connections

Roads

Housing

Houses (18 different variations)

Houses with garages (13 different variations)

Apartment buildings (6 variations)

Skyscrapers

Landscaping

Trees

Parks

Statues

Services and commercial

Shopping malls

Supermarkets

Stadiums

Museums

Police stations

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Parking lots

Fire stations

Schools

Bus stations

Auto repair shops

Barber shops

Coffee shops

Small mall

General shops (9 variations)

Office buildings (12 variations)

Airports

Christmas market

Fireworks

Energy

Power cables (high, medium, low voltage)

Coal power plants

Nuclear power plants

Wind power plants

Solar power plants

Transformers between voltage levels (high to medium, medium to low)

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Communications

ISP buildings

ISP substations

Fiber cables

Small antennas

Large antennas

Transport

Cars

Utility vehicles (police cars, firemen, ambulances, buses, trucks)

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Annex D: Template for scenario design

NAME OF THE SCENARIO

_____

DESCRIPTION

_____

NUMBER OF ROLES

o	1	o	2	o	3	@	4

BUDGET

@	Common to all roles

Value _____

o	All roles have the same budget

Value _____

o	Each role has its own budget

TIME

Using season OFF

Starting season (1 season = 90 days, 1 year = 360 days)

@	Spring	o	Summer	o	Fall	o	Winter

Scenario Duration in Days 60

Using Weather OFF

Using Night and Day cycle OFF

EVENTS

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Using Events	OFF

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Annex E: Template for role creation

ROLE NAME

_____

ROLE DESCRIPTION

_____

ROLE INTRO TEXT

_____

ROLE BUDGET	10000

ROLE CAPACITIES

o	Build Everything	o	Bulldoze Everything
v	Build Housing	v	Bulldoze Housing
o	Build Commerce	o	Bulldoze Commerce
o	Build Industries	o	Bulldoze Industries
o	Build Infrastructure	o	Bulldoze Infrastructure
v	Build Public Services	v	Bulldoze Public Services
o	Build Culture	o	Bulldoze Culture
o	Terraforming		
o	Terrain Zoning		

ROLE OBJECTIVES

o	My Department Treasury	____	(Number)	o	Industrial Proportion	____	(%)
o	City Treasury	____	(Number)	o	Fire Station Coverage	____	(%)
o	City Income	____	(Number)	o	Police Station	____	(%)

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					Coverage		
o	City Expenses		(Number)	o	Hospital Coverage		(%)
o	Happiness		(Percentage)	o	School Coverage		(%)
o	Population		(Number)	o	(number)		Of
o	Energy Coverage		(Percentage)	o	Commercial income		(Number)
o	Pollution Coverage		(Percentage)	o	Tourism amount		(Number)
o	Phone Coverage		(Percentage)	o	Traffic amount		(Number)
o	Internet Coverage		(Percentage)	o	Culture		(Percentage)
o	Crime		(Percentage)	o	Health		(Percentage)
o	Housing Proportion		(Percentage)	o	Education		(Percentage)
o	Commercial Proportion		(Percentage)				

3 timescales

Real life

ingame engine (ecity)

360 days

each real life day = 360/15 ingame day

ingame displayed second = Time factor

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Annex F: Template for role objective definition

ROLE
OBJECTIVES

o	City Treasury	_____	(Number)
o	City Income	_____	(Number)
o	City Expenses	_____	(Number)
o	Happiness	_____	(Percentage)
o	Population	_____	(Number)
o	Energy Coverage	_____	(Percentage)
o	Pollution Coverage	_____	(Percentage)
o	Phone Coverage	_____	(Percentage)
o	Internet Coverage	_____	(Percentage)
o	Crime	_____	(Percentage)
o	Housing Proportion	_____	(Percentage)
o	Commercial Proportion	_____	(Percentage)
o	Industrial Proportion	_____	(Percentage)

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