Project LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry

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O2. Collaborative and agile methodological learning frameworks for promoting higher education student preparedness to enter the world of work

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Authors: H. Tsalapatas, S. Kourias, D.Stylla, O Heidmann

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CONTRIBUTORS

Carlos Vaz De Carvalho

Paula Escudeiro

Triinu Jesmin

Kai Pata

Martin Sillaots

Manuel Caeiro Rodriguez

Nadia Vlahoutsou

Janet Read

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EXECUTIVE SUMMARY

In engineering principles the knowledge students build while enrolled in higher education may become to a large degree irrelevant a few years after graduation as a result of the fast evolution of technology in innovation related sectors. In this context, the capacity to think critically and to learn-to-learn is as important, if not more, as the base knowledge developed through formal curricula. In addition, to facilitate an effective transition to the professional world higher education must expose students to industry practices and processes rather than be limited to the development of core knowledge. This exposure may be achieved to a certain degree through specific courses; more effectively, it may be achieved through the integration of industry processes into curricula thus enabling students to use new skills and competencies in a learning environment that simulates the way industry deploys knowledge.

LEAP aims at building 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. Lean practices will encourage students to design solutions that meet needs while minimizing the deployment of resources. Agile practices will expose them 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.

LEAP will pursue these objectives through the design and development of serious games that encourage learners to adopt industry roles, to think critically for addressing community and societal needs through agile engineering solutions, to practice on the application of industrial process management in the context of their higher education curricula, and to take into account environmental responsibility issues in service design and implementation.

1. RATIONALE

Higher education prepares learners for their future role as professionals and active citizens in multiple ways: it builds field specific knowledge; it builds learning-to-learn capacity that empowers students to develop knowledge in life-long learning contexts throughout their careers in a constantly evolving job market; it prepares students to effectively make the transition from the educational environment into the professional world, to become effectively integrated into the professionally community, and to adapt to market-driven processes. According to the Modernization Agenda for Higher Education, the Universities seem to be forced to tackle with multiple challenges in their quest to promote creative and critical thinking in order to help students in order to become adaptable citizens and professional. Such challenges have a direct connection with economic crisis, youth unemployment, integration of new technologies and modes of working, and so forth. However, according to the Communication on Opening-up Education, the need to stimulate innovative ways of teaching and learning through new technologies and digital content is rather important in order to exploit the opportunities of the digital revolution in educational contexts thus alleviate the “new digital divide” and in fact re-engage that 50-80% of students that has never used digital content.

In engineering principles the knowledge that students acquire during their higher education studies is bound to become obsolete to a large degree in the course of the years after graduation and this can be fully justified by the fast advancement of methods and technologies in innovation related sectors. In this context, critical thinking and metacognitive skills and students’ experience with industry practices and processes are highly important in order to facilitate their effective transition to the professional world. The exposure to the aforementioned context may be achieved to a certain degree through specific courses but it could become even more effective through the integration of industry processes into curricula that will enable students

to use new skills and competencies in a learning environment that simulates the way industry deploys knowledge.

The LEAP project aims at promoting in engineering higher education emerging learning design linked to industry practices in order to help students make an effective transition into the professional world. More specifically, the project promotes lean and agile learning design and methodologies that enable 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. Lean practices familiarize students with clean production cycles in which non-essential elements of the production process are eliminated with the objective of containing production costs.

LEAP develops of a serious game that will encourage its users-learners to adopt industry roles, to think critically for addressing community and societal needs through agile engineering solutions, to practice on the application of industrial process management in the context of their higher education curricula, and to take into account environmental responsibility issues in service design and implementation. Recognizing the importance of supporting educators on integrating the proposed innovative learning methods and tools into their teaching practices LEAP will further develop good practice guidelines and instructor support content. The outcomes will be validated in real-life contexts in classrooms in Greece, Portugal, Spain, Estonia, and the UK.

This report is organized as follows:

- Chapters 2, 3, 4 and 5 present respectively the objectives and expected outcomes of the LEAP project, its innovative potential, as well as the targeted groups of users and stakeholders.
- Chapter 6 presents and analyses the basic concepts, strategies and practices regarding lean production and agile manufacturing.

- Chapter 7 deals with the evolving landscape of higher education and the challenges that drive innovation while Chapter 8 focuses on the national strategies and policies regarding the link between learning practices and industrial policies.
- Chapters 9 and 10 present the current situation in countries represented in the consortium through partner organizations in terms of linking learning processes to industrial practices and entrepreneurship either with or without ICT deployment.
- Chapter 11 presents an analysis and definitions of learning requirements for learners and educators.
- Chapter 12 focuses specifically on the current situation in relation to serious games deployment in educational contexts for the development of specific professional skills. In addition, it analyses the requirements for higher education instructors on deploying ICT.
- Chapter 13 presents the LEAP pedagogical and methodological active learning framework.

2. LEAP HIGH LEVEL OBJECTIVES

LEAP addresses directly the objectives of the 2011 EU Modernization Agenda priorities. Specifically, the Agenda states that higher education as a sector must address a wide range of challenges in its quest to build critically thinking, creative and adaptable adults. The challenges include the economic crisis, youth unemployment, integration of new technologies and modes of working, and more. The LEAP project promotes both the development of critical thinking, creativity, and adaptability by preparing higher education students to enter effectively the world of work in innovation related sectors (such as engineering) by being exposed in the context of their formal curricula to industry practices such as lean and agile product and service design approaches, by promoting entrepreneurial thinking for creatively addressing real-world needs through engineering solutions, by instilling user-centred mind sets among students challenging them to design solutions with the needs of the end-users / consumers in mind. The methodology proposed by the LEAP project promotes both the development of basic knowledge in engineering subjects as well as analytical thinking and the capacity of learners to effectively transition into the world of work thus promoting employability especially in youth.

LEAP further addresses the objectives of the 2013 Communication on Opening up Education and aims to promote the design, implementation, and deployment of innovative digital learning content specifically in University courses in order to help establish the necessary links between practices in the higher education sector and industry. LEAP aims to promote the shrinking of the "new digital divide", a term that implies the lack of use of digital content by a high percentage of students, estimated at around 50-80%, through the promotion of innovative digital content in the form of simulations and serious games, by promoting the link of digital content to emerging learning design based on active learning practices that simulate industry processes, by educating teachers and instructors on the deployment of emerging digital content in the classroom, and by multiplying the outcomes

through the dissemination in a wider community of policy makers and educator associations aiming at wider adoption of results.

3. EXPECTED OUTCOMES

The following results are foreseen from the implementation of LEAP objectives and activities:

- **An active, collaborative methodological learning framework that deploys serious games** for building experience among higher education students on emerging industrial processes, such as agile and lean production design, thus preparing them for transitioning effectively into the world of work. The proposed learning framework will encourage learners to think entrepreneurially and in a user-centred manner when designing solutions for real-world problems. It will promote positive attitudes on collaboration raising awareness on the fact today's truly successful services and products are the result of great teamwork. Agile learning processes will further allow students to influence the learning process in relation to their interests and needs taking into account industry requirements for employment, thus promoting the competitiveness and employability of learners as future professionals.
- **A proof-of-concept serious game** for promoting the integration of industrial processes, such as agile and lean production design, into higher education practices. The serious game will challenge learners to design solutions that address real-world issues following agile design approaches in which input from users is taken into account throughout product or service development and is integrated into product or service design in an iterative manner, rather than only in the beginning of the implementation cycle, ensuring that the final outcome best meets end-user needs. In addition, the game will encourage learners to consider sound resources management in-line with lean production processes. The interface will be available in Greek, Estonian, Spanish, Portuguese, and English.

- **A user guide on the proposed serious game**, which will act as a reference on game use; the guide will be available in Greek, Estonian, Spanish, Portuguese, and English.
- **Instructional support content in the form of good practice videos** that will facilitate the integration of proposed agile learning methodologies and serious game into existing higher education practices, enriching learning for the benefit of the ultimate end-users, i.e. learners and educators.
- **End-to-end learning activities based on the proposed serious game** for building experience on emerging industrial processes, including agile and lean design. The activities will be documented into learning sheets targeting instructors. The learning sheets will facilitate the easier integration of the proposed game-based learning framework into existing instructional practices. The learning sheets will be available in Greek, Estonian, Spanish, Portuguese, and English.
- **An evaluation strategy** that will provide a comprehensive guide on how the relevance, acceptance, effectiveness, and quality of the LEAP serious game and instructional support content will be established through formative and qualitative evaluation methodologies. The strategy will provide insight to external interested parties, including teachers and policy makers, on how to evaluate the proposed learning frameworks and software tools in relation to desired and expected learning outcomes on employability.
- **Evaluation outcomes** from the deployment of the LEAP methodologies and tools in real-life educational contexts in Greece, Spain, Portugal, Estonia, and the UK with the objective of generating objective feedback with a European footprint on learning outcomes resulting from LEAP activities in diverse educational, cultural, and economic environments.

- **Conference publications** targeting the academic community and industry and presenting in a professional / scientific manner information on project objectives and implementation activities.
- **Contacts with policy makers, educators, instructor trainers, professionals, and other stakeholders** with the objective of disseminating project results and promoting uptake of outcomes as well as a project portal that will facilitate dissemination will provide instructional support content to the targeted stakeholders. A project newsletter will be also published online on a systematic basis during the project implementation.
- **Informational material in the form of leaflets, posters, and promotional project videos** that will present in an easy to understand manner targeting the general public project objectives, activities, and outcomes as well as Internet and media publications for reaching widely the identified stakeholder groups and/or the general public on expected project benefits to learners and teachers.
- **Multiplier events** in Greece, Estonia, Portugal and the UK. The event in Portugal will be an international one with an audience from both Portugal and Spain. Events will target instructors, students, policy makers, and the general public and they will promote project outcomes and results.

4. LEAP INNOVATION

The project introduces an agile, collaborative learning design approach. Agile product and service design is highly relevant in industry, and more so in engineering, for ensuring that products and services address effectively the needs of end users and society. Agile design refers to product development in cycles of design, implementation, and evaluation phases. The design and implementation processes are not separated; rather, design is revisited several times throughout product development for enhancing the product characteristics based on input from end users. This approach ensures that the final product more effectively addresses real world needs. In educational contexts, agile learning refers to the design of learning activities that follow industrial agile product and service design processes. Agile learning design is particularly relevant in game-based learning approaches adopted by LEAP in which a software application, i.e. a serious game, is at the centre of wider blended learning activities. LEAP further promotes collaborative agile approaches, highlighting the fact that success stories in industry are the result of great teams working effectively together, as opposed to individual work.

LEAP is innovative in many ways: in its **educational objectives**, the **learning methodologies and pedagogic scenarios** that the consortium proposes in the wider framework of suggested best practices and the **technology** deployed for educational purposes.

In terms of **educational objectives** the project addresses real needs in higher education at a European level and specifically:

- The need to align higher education practices to industry needs by updating higher education practices with initiatives that exposed students to industrial processes, such as agile and lean production design.

- The necessity to update higher education practices through technology designed for educational use, such as serious games, with the objective of bringing higher education into the digital era.
- The need to develop open digital educational resources for free use at the higher education level for free use in formal and informal learning contexts

The above are pursued in LEAP through the proposed solution that combines learning design and technology, and specifically agile learning frameworks and serious games software applications, for simulating the introduction of educational initiatives in classrooms that allow learners to build, through simulations, experience on real-world industry needs.

LEAP is also innovative at the **learning intervention and practices** field as it:

- Promotes active learning by doing, which has been seen to significantly contribute to knowledge retention (FAS).
- Links gaming to specific learning objectives through scenarios that are inspired by real world work practices.
- Contributes to linking learning activities to desired learning outcomes through immediate feedback.
- Promotes knowledge transferability to other subjects through role playing.
- Promotes critical thinking, which is an inherent part of agile design.
- Encourages entrepreneurial mind sets, which are directly linked agile industrial practices that are inherently user-centred.
- Promotes long-term engagement with learning through applications that attract and retain the interest of students.

In terms of **technical implementation** LEAP validates the proposed learning methodological design described above through the design and software implementation of a serious game environment in which learners will be encouraged to design and synthesize solutions that address specific world needs. Learners will be encouraged to follow agile and lean product design through a serious game that simulates real-world industry processes and exposes learners to innovative thinking mind sets related to deploying technology for addressing specific needs of users in a human-cantered solution as well as minimizing production costs through lean processes that conserve resources and respect the environment. Serious games design help scaffolds knowledge through role-playing, feedback related to student actions that helps them understand the impact of their choices by making the connection between cause and effect, long-term engagement in learning processes through gamification mechanisms that maintain learner interest such as rewards, collaboration, recognition of achievement, and others, and peer learning through which learners will be encouraged to share knowledge and to help each other build experience on emerging industrial design processes.

5. LEAP STAKEHOLDERS

What follows is a short analysis of the precise map of stakeholder groups that stand to benefit directly or indirectly from innovative pedagogical interventions that promote the exposure of higher education learners to agile and lean industrial design and prepare them for entering the world of work.

Direct stakeholders include:

- **Higher education students**, whose interests include enhanced preparedness for entering the world of work through exposure to industrial practices in the course of their studies; in addition, their interests include enhanced skill sets and enhanced employability. Through LEAP, they will get exposed either to active learning by doing, which has been seen to significantly contribute to knowledge retention (FAS) or to scenarios that are inspired by real-world work practices. This way, learning activities can be linked to desired learning outcomes through immediate feedback while knowledge transferability to other subjects will be pursued through role playing. Higher education students are expected to develop critical thinking, which is an inherent part of agile design and it encourages entrepreneurial mind sets, which are directly linked to agile industrial practices that are inherently user-centred. Last but not least students will benefit from long-term engagement with learning through applications that attract and retain their interest.
- **Higher education instructors**, whose interests include the enhancement of their teaching practices for the benefit of their students. They will pursue better understanding of the benefits for higher education students of the integration into learning practices of activities that prepare them for an effective transition into the world of work through their exposure to industrial processes, such as agile and lean production. Instructors are also expected to develop better understanding of the benefits of sound industrial processes, such as agile

and lean production design to society and the environment through the development of products and services that address real world needs (agile design) and through the minimization of production costs (lean production). They will have the chance to gain access to the proposed innovative methodologies and tools / serious games that will be built through LEAP towards building experience on industrial processes through innovative combinations of collaboration, agile, and game-based learning approaches for higher education. Besides, through their participation in the design, implementation, and evaluation of proposed LEAP learning frameworks and proof-of-concept software tools, instructors will have the opportunity to influence the focus, design, and implementation practices of the LEAP tools that contribute to the preparedness and interest of learners in industrial design processes. Another important and positive impact is the enhancement of the capacity of educators to integrate innovative ICT and emerging pedagogical frameworks into existing lifelong learning offerings targeting young learners.

Indirect stakeholders span wider but equally important groups, including:

- **Educational policy makers**, whose interests include an analysis of the emerging learning design and technologies with the objective of promoting innovation in learning and enhancing learning experiences. In addition, their interests include the better alignment of higher education design to industrial needs with the objective of promoting employment. Policy makers will also develop a better understanding of the higher education sector needs in relation to aligning educational practices to work needs and they are also expected to pursue enhancement of learning practices through serious gaming approaches that bring higher education into the digital era. Another significant impacts relates to the policy makers' better understanding of the needs of employers in relation to their ability to develop policies that can engage effectively prepared higher education graduates into

their fast moving business practices. LEAP is also expected to help policy makers in their focus on the benefits of strategic uses of ICT, and specifically game-based learning combined with break through agile pedagogical frameworks, for building the necessary skills and positively influencing attitudes in relation to the need to link higher education practices to industry.

- **Educational software designers**, whose interests include analyses of the impact of emerging technologies, methodologies, and tools in learning that can help shape future initiatives, services, and products in technology-enhanced learning.
- **Parents**, whose interests include the personal, academic, and professional well-being of their children as well as **the general public**, whose interests are social cohesion, sustainable growth, and quality of life through a better matching of skill sets of the next generation to community and industry needs.
- **The academic community in learning design**, whose interests include all outcomes of the LEAP project such a methodological educational design, services and tools, supporting content, and evaluation results
- **SMEs and industrial players** that play the role of prospective employers. These stakeholders are expected to develop their capacity either to effectively spot trained personnel that is effectively prepared for engaging in professional activities or to enhance competitiveness through better matching of staff (and particularly young staff) skills to organizational business objectives.

6. LEAN PRODUCTION AND AGILE MANUFACTURING CONCEPTS, STRATEGIES AND PRACTICES

6.1 Short introduction to agile and the general idea behind agile

According to Sheridan (1993), since the 1980s, industry analysts have popularized the terms “world-class manufacturing” and “lean production” in pursuit of flexibility, advanced levels of quality and efficacy either in products or in customer service and shortened lead-times. On the other hand, the “high expectations” and increased interest of customers, along with increasingly globalised markets have forced industry -and still do so- to rethink and transform business strategies. For this reason, about a decade ago, the agile manufacturing paradigm was introduced in response to the constantly changing “new world economical order” and as a basis for returning to competitiveness and global prosperity. While agility may reflect different concepts to different enterprises and business sectors, due to the diversity of contexts, objectives and needs, its essential concepts are encapsulated in the elements of cooperativeness and synergism, strategic vision that enables the ability of knowledgeable workforce to come to terms with continuous and unpredictable change, to create and deliver customer-valued, high quality goods and/or services within a consistent and unified (electronic) network of equally respected partners.

Agile manufacturing is a strategy that can create flexible or virtual organizations to meet increasing customer expectations. It has developed from the concept of lean production currently being employed increasingly in manufacturing industry. Whereas lean methods offer customers good quality products at low price by removing inventory and waste from manufacturing, agile manufacturing is a strategy for entering niche markets rapidly and being able to cater for the specific needs of ever more demanding customers on an individual basis.

The concept of agile manufacturing, as a new manufacturing paradigm, was coined at Iacocca Institute, Lehigh University in 1991 by a group of researchers that conducted a study which aimed at identifying the important practices in various aspects of manufacturing firms during their investigation. They defined agile manufacturing as "…a manufacturing system with extraordinary capabilities (Internal capabilities: hard and soft technologies, human resources, educated management, information) to meet the rapidly changing needs of the marketplace (speed, flexibility, customers, competitors, suppliers, infrastructure, responsiveness). A system that shifts quickly (speed and responsiveness) among product models or between product lines (flexibility), ideally in real-time responding to customer demand (customer needs and wants)".

Afterwards, a considerable number of studies have been conducted in this area but a researcher, whose work is placed among the most influential in the field of agile manufacturing, is Gunasekaran & Yusuf (2002) according to whom, "agility" is based on the concepts of co-operation, of investment in people and information, of value-based pricing strategies and of organizational mastery of unpredicted contexts and changes. Goldman et al. (1995) argue that Agile Manufacturing comprises the characteristics of lean production, extended to incorporate the following basic principles:

- End products represent tangible solutions to customers' individual problems.
- Virtual organizations, thus virtual networks that consist of disseminated entities whose work and communication is supported by ICT, are formed on the basis of products that appear in the market in minimum time through internal and external co-operation.
- The aforementioned organizations grow thanks to entrepreneurial approaches that they adopt in order to efficiently face change and uncertainty.

- Emphasis is on flexibility, adaptability and the ability to tailor every product to precise requirements as means of serving increasingly sophisticated customer demand and extending this flexibility back to product design and new product introduction through such techniques as rapid prototyping.

One more influential work regarding AM is the one by Yusuf et al (1999) that describe knowledge-driven operations, core competence management, virtual enterprise formation and flexibility-capability for re-configuration as the four key concepts for AM. Yusuf et al (1999) argue that core competence of individuals refers either to the skills and knowledge of workforce or to corporate capability to evolve, learn, integrate various skills and technology, and collaborate within its own ecosystem. In addition, the capability to work as an online, virtual enterprise enables “companies to come together and deliver quality, scope, and the scale of products and services which they would not have been able to provide individually” (Yusuf et al, 1999). Furthermore, flexibility and capability for re-configurability refers to the ability of an agile firm to easily shift its focus, re-configure and re-align in response to possible drawbacks, new trends and opportunities in marketplace. Knowledge-driven enterprise, as the last component of Yusuf et al’s model, points out the necessity of an Agile organization to motivate, train and equip its workforce with the right set of skills and knowledge that can lead to competitive solutions, productivity and efficiency.

Others seem to share a similar view about AM and identify it with “lean” manufacturing as well as with “flexibility” and “responsiveness” to changes and according to their theoretical model, AM is built on ten pillars that are founded on lean philosophy and its tools:

- Focus on core competencies.
- Teamwork.
- Rapid prototyping.

- Continuous improvement.
- Multi-skilled and flexible workforce.
- Empowerment.
- Virtual enterprise.
- ICT (Information and Communication Technologies)
- Concurrent engineering.
- Change
- Risk management.

While for many the terms “lean” and “agile” manufacturing might sound similar and sharing a common basis, however, they are different is specific aspects. “Lean” is linked to manufacturing processes with limited resources but as a clear response to high customer expectations and competitive pressures. In addition, “lean” refers to a collection of operational processes linked with the highly productive use of resources. On the other hand, according to Goldman et al (1994) “agile manufacturing” seems to offer practical answers to complex issues caused by continuous change and might be considered as an overall strategy focused on securing excellence within an unpredictable environment not to mention that it focuses mainly on the individual customer in order to build highly interactive producer-customer relationships.

The general idea behind agile is that a project needs to be flexible and evolving, of course adaptive. Never-ending writing and speaking has explored how the manifesto could be interpreted and many specific frameworks and methodologies have been developed to formalize its principles, including extreme programming [i](programming in very short implementation cycles), Kanban (a scheduling system for agile), SCRUM (another popular scheduling system). A whole “agile industry” has emerged and numerous compa-

nies offer tools and training but also consulting, certification, and other products and services. The economic engine behind the agile movement is significant.

Agile is arguably not appropriate for every project or industry. It fits where elements of novelty occurs (such as evolving requirements, changing priorities and flexible deliverables). Agile approach is not effective for industries where product blueprints must be well defined before implementation begins or in large, distributed organizations which set organizational cultures. Agile is more appropriate for small implementation teams that work well together and are experienced. It further requires close collaboration with the customer during the implementation processes.

The agile approach is significant for many industries beyond software development, such as user experience (UX) design. Applying agile approaches in other industries can take months or even years to figure what's working and what's not. Similarly, the many tools available make no sense in non-software contexts, leaving those teams to fend for themselves, inventing new project tracking systems with spreadsheets or whatever else works.

The agile approach may be difficult to implement. Similarly with any outstanding philosophy, by implementing it, humans execute agile in an imperfect way that gets things messed up. A controversial 2012 report from VOKE introduced some stern criticism of the agile approach. Overall, writers Liza Dronzek and Theresa Lanowitz claimed that agile movement can be described either as a developer rebellion against unwanted tasks or as a chance of selling agile services or even as a guise of avoiding documentation. Furthermore, VOKE continued by supporting the fact that "sixty-four percent (64%) of survey participants considered that agile appeared to be either confusing or hard or slow and only twenty-eight percent (28%) of the participants mentioned success with agile". Summarising, the authors also

reported that 40% of participants that used agile did not understand the way they benefited from the process.

Transition to emerging new frameworks of work can be confusing. Humans aren't great at transitions. In most belief systems, such as agile, the core principles are actually really great. Unfortunately, most of the participants will possibly understand the principles of work poorly, and as a result they will execute them poorly. If a team is lazy agile won't make it productive. If a team's sloppy and haphazard, agile won't make it organized. However, if there are people working on projects in which agile is appropriate, they will probably do better with agile than without it because its "manifesto" emphasizes the value of people. Moreover, it emphasizes the value of interaction. In practice, this means that the whole team can stay well updated in on the activities of its members because of frequent communication both within the team and with the customer. Communication I agile processes includes frequent team meeting, referred to as SCRUM meetings, which can be daily and help maintain a consistent feedback loop. This loop helps teams act in accordance with customer input, beta tester input and market data.

The agile process also emphasizes the manufacturing of on-time and on-budget deliverables. It is not correlated with perfection, as products can mostly be tweaked later in the implementation process. This is the reason why agile iterations are short and appear to have more feasible goals. In addition, these goals lead to further iterations and this procedure also affects the relationships with clients. The traditional design process aims to display the best version of the product to clients. This begins in the proposal and research phase, in which the practitioners use PSD mock-ups and move on the next phase until they arrive at the final approval phase. As it is widespread, clients usually perceive what they really need as a product comes together. Additionally, market demand changes more abruptly than designers can produce results. This can be frustrating. Adopting an agile approach of looping clients into every phase of the process and producing a constant stream of deliverables can solve this problem as it allows clients

to really participate in the whole process and feel they have the final say. Clients can vision how their requirements can adhere to a real world context. The more frequent the communication is the better a team can incorporate changes.

Regular testing is also an important factor of the whole procedure. In agile development, developers carve up bigger problems into smaller ones. Testing of this work help them correct the mistakes or even transfer them into the next iteration. This dispenses the developers from paralysis that occurs when too much is approached at once. In this way, frequent testing and a problem solving mentality can not only keep the design process on track but fuel creativity as well as it averts designers from getting too caught up on the biggest problem of all, namely knowing from very beginning exactly how a product should look and feel. It is valuable to zoom back up to the macro level and this can't be ignored; otherwise, designs will become too disjoint. It is rather efficient for a team to take a step back when changes occur or when external input does not fit well with original plans because moving backwards is not baneful. Rather, it proves the commitment to figure out the best way to function.

6.2 Historical retrospective of the agile (software) development

Agile software development could be described as a procedure that is banked on definite principles. There are some significant requirements that, if followed, solutions are shaped and developed towards implementing software (Collier, 2011). It advocates adaptive planning, development that blossoms continuously, early delivery and uninterrupted improvement. Furthermore, it fosters change for introducing a version of the product that is better than the one it replaces. These principles ought to be examined as they corroborate the delineation and the ongoing development of many software approaches (Larman, 2004). It wouldn't be proper to omit the fact that the term agile was first coined for this use in 2001 in the Manifesto for Agile Software Development. Although it is initially written as Agile (with a capital

A) this is gradually becoming deprecated. The historical retrospective of agile is of a great importance since it explains the context of its hidden principles and how the previous software development methods affected agile. It further explains the necessity of this approach.

Agile is a highly innovative method that is applied mostly in software engineering but it is emerging in various other engineering fields. Nevertheless, agile effectiveness has been questioned and this is why both the Agile Manifesto and the principles of agile will be elaborated thoroughly in this report. The team maturity scale is a determining factor in relation to how ready a team is to incorporate agile within its process.

This historical flashback depicts how it all started and it presents what led to the agile approach. This is the reason why the historical retrospect will be expanded to each of the ancestors that led to the so-called agile methods. A flashback shown below documents the development of the software methods that steered to the present-day agile design and development method:

- **Incremental Software Development Methods:** They emerged in 1957 (Larman and Victor, 2003). The basic idea that lies behind these methods is to build a system through repeated cycles, i.e. an iterative system, permitting software engineers to seize upon what was learned from the past: Communication is of a great importance so as to grasp the objective of a project. Planning allows the members of a team to work simultaneously on different parts of the same project at a different time. Modelling refers to both data and process. Construction reuses software components and automatic coding and deployment, namely the integration of each of the increments, i.e. software releases, that have been identified.
- **Evolutionary Project Management:** These methods were introduced in the early 1970s. They refer to flexible project management and adaptive software development (Edmonds, 1974).

- **Adaptive Software Development (ASD):** ASD was first released in 2000. Jim Highsmith was its inspirer. ASD's practices enable change and are flexible in belligerent environments. ASD is a cyclical model in which the name of each phase bespeaks the unpredictability that exists in laborious systems. The phases of this approach are to "speculate", to "collaborate" and to "learn". These phases illustrate the fact that it can be characterised by dynamism. According to its inspirers, "the Adaptive Development elaborately replaces Determinism with Emergence". The most important typicality of ASD Lifecycle is the fact that it dwells on results, not tasks, which are identified as application features.

During the 1990s, a variety of lightweight software approaches arose in reaction to the dominant heavyweight ones. These approaches include: rapid application development was introduced in 1991 (Martin, 1991; Kerr & Hunter, 1993); it was followed by the unified process and dynamic systems development method (DSDM) that was published in 1994; SCRUM appeared for the first time in 1995; Crystal Clear and eXtreme Programming (XP) arose in 1996. Last but not least, in 1997, Feature-Driven Development (FDD) was published. These approaches are considered to be agile methods although that they existed before the publication of the "Agile Manifesto". What comes next is a short clarification of these approaches, before analysing the real agile method, since it is necessary to understand the background of agile method.

- **Rapid Application Development (RAD):** RAD consists of four phases that can be explained by Martin (1991) as it follows: **requirements planning, user design, construction and the cutover phase**. The first synthesizes elements not only of planning but also of systems analysis. In the second, users cooperate with systems analysts, develop models and prototypes by using Joint Application Development (JAD) techniques and CASE tools in order to adapt user requirements into working models. The third is similar with the

SDLC. The last contains testing, data modification and user coaching. In comparison to traditional methods this entire process is compressed.

- **Unified Process and Dynamic Systems Development Method (DSDM):** There are eight principles in DSDM that, on account of brevity, cannot be expatiated in the present report.
- **SCRUM (Software Development Method):** SCRUM can be used for running entire organizations since it is an iterative and incremental agile software development framework for managing product development. Its most significant feature is the fact that it offers requirement volatility to users considering that during product development, customers may change their minds about what they want and need. The flexibility of SCRUM allows the implementation team to address unpredictability in the development process. Trust and openness must characterise the implementation team. There are five values that represent SCRUM: **commitment, courage, focus, openness** and **respect**.
- **Crystal Clear (Software Development Method):** Crystal Clear belongs to the **Crystal** family of methodologies that was described by Alistair Cockburn and is considered as a paradigm of an agile or lightweight implementation methodologies. Crystal Clear can be applied to teams that consist of six or eight developers and are occupied with non-life critical systems. The Crystal family focuses mostly on effectiveness as a component of project's safety. Crystal Clear focuses on people not on processes or artefacts. Crystal Clear requires regular delivery of usable code to users, pensive improvement and osmotic communication ideally by being co-located. This approach contains optional properties some of which are personal safety, easy access to expert users, frequent integration, configuration management and so on.

- **Extreme Programming (XP):** In 1999 extreme programming consisted of four values but subsequently one more was about to incorporate: “communication, simplicity, feedback, and courage”. Respect was added in the second edition of “Extreme Programming Explained”. Those values will not be described since this report simply cites the historical facts of the agile. The XP principles rely on the values described and are intended to promote decisions in a system development project.
- **Feature-Driven Development (FDD):** FDD practices are directed to a client-valued functionality perspective. FDD is a model-driven short-iteration process. It consists of five fundamental activities: develop overall model, build feature list, plan by feature, design by feature and build by feature.

6.3 Examining agile principles

The members of the Agile Alliance refined the philosophy that is captured in their manifesto into a collection of twelve principles in order to help people perceive what agile is all about. These principles are presented and clarified below, by explaining briefly what each of them supports:

- “Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage”. The goal of the software development should be the software up growth. Defining everything up front is a traditional technique. Nevertheless, an evolutionary approach, as the one promoted in agile design, may have more efficacious results in specific contexts[ii].
- “Requirements will inevitably change throughout a software development project”. Traditional software developers will often apply change management processes, but change cannot be prevented or

even avoided. Agilists are receptive to change and face requirements as a prioritized stack, which can be altered over time.

- “Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely”. The delivery of software furnishes with tangible feedback while providing enhanced guidance for the development team.
- “Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely”. People that participate in the project should be active in the project to be successful. Agile developers apply practices like onsite customer and active stakeholder participation. They adopt comprehensive tools and techniques that enable stakeholders to be vigorously involved with software development.
- “Build projects around motivated individuals. Give them the environment and support their need and trust them to get the job done”. Many businesses hire unskilled people since there is a belief that supports that and if furnished them with a CMMI or an ISO certificate these employees will be capable of developing software. Agile teams, on the other hand, need people working together collaboratively and learn from each other. These people have the humility to respect one another.
- “The most efficient and effective method of conveying information to and within a development team is face-to-face conversation”. Succeeding in a (software) development team means efficient communication and cooperation. People have the ability to communicate with one another in various ways but the most effective way is face-to-face communication.
- “The highest priority is to satisfy the customer through early and continuous delivery of valuable software”. The primary measure of software development should be the delivery of working software, which

meets the changing needs of its stakeholders, not some form of "earned value" measure based on the delivery of documentation of the holding of meetings.

- “The best architectures, requirements and designs emerge from self-organizing teams”. People aren’t able to develop software successfully by being forced to work overtime continuously. Resulting in high quality, intellectual work can last 5-6 hours per day. During the rest of the day they can be occupied with email, meetings, water cooler discussions and so on, but people's ability to do "real work" is restricted. If forced to work for 12 hours a day, people will feel weary and the result will be a twelve-hour mediocre work a day.
- “It is way easier to grasp, maintain and evolve high-quality source code than to work with low-quality code”. Therefore, agilists are occupied with refactoring, they stay on track and they take a test-driven approach to examine every single case. They also adopt and follow development guidelines and sometimes even modelling guidelines.
- Agile developers struggle hard because they consider that optimizing the stakeholder's ROI is really important, so they have to “automate” the work.
- The Agile Model Driven Development (AMDD) is the fundamental approach within the agile community. In addition, test-driven design (TDD) methods are fundamental too.
- Software Process Improvement (SPI) intends to improve an approach interwoven to software development.

6.4 Analyzing agile’s practicality and efficiency

Agile development is supported by a number of concrete practices covering areas like requirements, design, modelling, coding, testing, planning, risk management, process, quality, etc. Some notable agile practices include Acceptance Test-Driven Development (ATDD), agile modelling, backlogs

management (product backlog management and sprint backlog management), Behaviour-Driven Development (BDD), Business Analyst Designer Method (BADM), Cross-functional team, Continuous integration (CI), Domain-Driven Design (DDD), Information Radiators (SCRUM board, task board, visual management board, burn down chart), Iterative and Incremental Development (IID), Pair Programming, Planning Poker, Refactoring, SCRUM events (sprint planning, daily SCRUM, sprint review and retrospective), Test-Driven Development (TDD), agile testing, time-boxing, user stories, story-driven modelling, retrospective and velocity tracking.

The Agile Alliance has created an online guide that analyses the way of applying agile. A whole range of agile practices are mentioned in this guide. Every single practice from the aforementioned guide is important (Abrahamson et al., 2002).

Further analysis on the practicality of agile practices leads to the following significant aspects:

- **Iterative, incremental and evolutionary:** Most agile development methods carve up product development work into small increments that minimize the amount of up-front planning and design. Iterations (time boxes) typically last from one to four weeks. A cross-functional team is occupied with activities such as planning, analysis, design and implementation in each iteration. After each iteration, a working product is demonstrated to stakeholders and a release is produced. As a result of the short implementation cycles the overall risk can be diminished and the product can be adjusted to changes rapidly.
- **Efficient and face-to-face communication:** Except for the development method being used, each team should include a customer representative. In SCRUM terminology, the customer is the “product owner”. This person acts on the stakeholders’ behalf. The product owner is available to answer the developers’ questions. At the end of each iteration the customer representative re-examines progress,

helps re-prioritize the requirements and helps optimize the return on investment (ROI). Maximizing ROI is feasible only when a product is aligned to customer needs and company objectives. In agile software development an up-to-date summary of the status of the product developed is essential.

- **Very short feedback loop and adaptation cycle:** Using agile methods means that the people involved collaborate on a daily basis. A SCRUM meeting takes place every day in which all actors are present. It is a brief session during which team members inform each other briefly on the state of implementation achieved the previous day, make implementation plans for the coming day of work and discuss any roadblocks or impediments they predict to the extent possible.
- **Quality focus:** Specific tools and techniques are frequently used to upgrade quality and enhance the product development agility. Some noticeable ones are the deployment design patterns (namely the use of code snippets that address specific functions), domain-driven design (namely addressing sector specific information in product development), code refactoring (namely making software code effective), continuous integration of new features, pair programming (working in pairs), automated unit testing (effective testing techniques) and test-driven development.
- **Philosophy:** “Agile software development is mainly oriented to complex systems and product development that can be characterized by dynamic, non-deterministic and non-linear features”. These basic arguments and previous industry experiences have shaped agile development's favouring of other methods thanks to its adaptability.
- **Adaptive vs. Predictive:** Development methods range from adaptive to predictive. Agile methods lie on the adaptive side having as a key a "Rolling Wave" approach. This approach enables flexibility,

since it allows the milestones to change. An adaptive team is synchronized with emerging demands. Predictive methods usually emphasize the organization of prospective steps in detail and the way promotes the avoidance of anticipated risks. These methods can predestine the entire development process. What is more, they provide an explicit early phase analysis. Risk analysis is the main factor that determines the choice between adaptive methods (agile or value-driven) and predictive ones (plan-driven).

- **Iterative vs. Waterfall software implementation model:** In the waterfall implementation model the testing phase is separate from the development one. Timewise, the testing phase follows development. In agile development the testing phase is completed in the same iteration as programming. Having a value retrospective and software re-planning session in each iteration helps the team constantly adapt its plans. This iterative approach supports a product rather than a project mind set. Flexibility governs throughout the development process. Software has the ability to evolve in response to change.
- **Code vs. Documentation:** In a letter to IEEE Computer, Steven Rakitin reported "yet another attempt to undermine the discipline of software engineering" and translating "Working software over comprehensive documentation" as "We want to spend all our time coding. Remember, real programmers don't write documentation" (Rakitin, 2001). This is disputed by proponents of agile software development, who state that there are often better ways to succeed than writing static documentation.

6.5 The proof that agile method works

Adopting and then tailoring a software process to meet the team's needs is an important and difficult decision that has to guarantee the project’s success. There are numerous choices that can be categorized into prescriptive processes such as the Rational Unified Process (RUP), the OPEN process

and agile ones such as eXtreme Programming (XP), SCRUM, Disciplined Agile Delivery (DAD) and Dynamic System Development Methodology (DSDM). The most important query is how someone can determine whether an agile development methodology works within his or her environment. People are hesitant when they think about using agile. The first reason of being diffident is that agile software development methodologies are recently obtained. The oldest ones are defined in the mid-1990s. The Agile Alliance was loosely formed in the spring of 2001. Agile Modelling (AM) was first clarified in the autumn of 2000 and was published in March of 2002 as a book.

It is encouraging that people look for the agile validity. More and more academic conferences take place worldwide. Agile development approaches are optimized and are still being challenged as compared to traditional ones. Traditional methods are based on fundamental assumptions that were never questioned or examined. Nevertheless, progress is rapid.

It is considered that the expectations of people who seek proof that agile processes work aren't realistic. Geoffrey Moore, in the book “Crossing the Chasm” describes five types of profiles of technology adopters: the innovators (who chase new concepts forcefully), the early adopters (who purse the change at small ages), the early majority (that researches elaborately before adopting a new concept), the late majority (that is preoccupied with whether they are able to handle a new concept) and laggards (who don't prefer any changes at all). People who fit the profile of the innovator or early adopter gain brand-new information and then they need to tailor it for their needs. The early majority will wait for sufficient unproved evidence.

In February 2006 Scott Ambler wrote his belief about crossing the chasm. In August of 2007 he wrote that “based on the results of the DDJ 2007 Agile Adoption Survey[iii], agile had become mainstream[iv]. The majority, 69% of respondents were working on one or more agile projects and 85% of them indicated that they were working on two or more”. Ruefully, there are no

perspicuous rules to determine if the chasm from traditional to agile development processes is already crossed or not. Unfortunately, the question "where is the proof" is typically asked by organizations that fit the late majority or even laggard profiles. That happens simply because agile techniques are relatively new. Such questions don't seem to be fair.

Several difficulties exist that inhibit the adoption of agile processes. Previous work within the software metrics field may have set the "proof bar" too high. Furthermore, refactoring and co-location with customers must be examined and accepted by implementation teams. More time may be needed to generate tangible proof that the method is effective since the vast majority of agile methodologists are practitioners who are vigorously working on software projects and have little time to invest in the theoretical study of their techniques. The incentive of people asking may also be questioned. Do they really need proof or are they simply interested to deflate the innovators?

Another interesting observation is that that many of the people who claim that agile processes don't work confuse agile processes with "code and fix" approaches. This happens because well accepted criteria determining whether a project is agile or not do not exist, and so it may be difficult to distinguish agile accurately. Recently books such as "Pair Programming Illuminated" (Wesley, 2002) and "Extreme Programming Perspectives" (Wesley, 2002) have published some proof that agile techniques work. This is anecdotal evidence, however it provides good insight on the success of teams that work with agile processes. There is significant evidence that iterative and incremental development works. Craig Larman (2004), in Chapter 6 of his book "Agile and Iterative Development: A Manager's Guide" summarizes writings that are relevant with both iterative and incremental (I&I) development. He makes a very strong case that proof exists that agile software development does work. He further argues that practices such as incremental delivery and iterative approaches embrace change.

There is growing survey evidence that agile methods may be more effective than traditional ones. The DDJ 2007 Project Success Survey showed that “Agile projects had a 72% success rate, compared with 63% for traditional and 43% for off-shoring. The DDJ 2008 Agile Adoption Survey showed that people using agile lead to hope that agile will get a foothold. Agile strategies seem to be low-risk”.

Amber has only explored two of the scaling factors of the Software Development Context Framework (SDFC), in this case team size and geographic distribution. However, these two factors seem to be the ones people are most attracted to. The 2008 IT Project Success Rates Survey[v] analysed the issue of geographic distribution and found that agile works regardless of the level of team distribution.

In addition, shorter feedback cycles lead to greater success. Agile techniques, such as Test Driven Design (TDD), pair programming and Agile Model Driven Development (AMDD) have short feedback cycles, lasting minutes or hours, while traditional techniques have feedback cycles lasting weeks or months.

6.6 The agile design philosophy

Following is an analysis of agile philosophy. The discussion aims to reveal the secrets that lead to the success of agile design:

- **Agile designs are emergent, they’re not defined up front**. Agilists don’t need to get a fully documented set of models in place before they may begin coding.
- **Unit tests form much of the detailed design documentation**. An important side effect of this approach is that their unit tests does not only validate their code but they also form the documentation in the form of executable specifications. TDD is complementary to AMDD and is actually scaled by AMDD.

- **Design models need to be just barely good enough**. There is no need to model every single detail since the developer is competent enough to handle the details.
- **Multiple models**. Effective developers realize that each type of model has its strengths and weaknesses. Since software development is complicated one quickly realizes what he or she needs to know on a wide range of models in order to be effective.
- **There is only a need for a subset of the models**. Although there are many modelling techniques available the fact is that any given project team will only require a subset. Different jobs, different tools. Someone never needs all of their tools at once but they will use them somehow over time.
- **Each model can be used for a variety of purposes.** A UML class diagram (a diagram that describes objects) can be used to depict a high-level domain model or a low-level design, not to mention things in between. Never underestimate how flexible you can be with models.
- **Designers should also code**. Whenever a model is handed over to someone else to code there is significant danger that the programmer will not understand the model, will miss some of its nuances, or may even ignore the model completely in favour of their own approach. In short, separating design from programming is a risky; it is far more effective to have generalizing specialists on the team that can both design and code.
- **Prove it with code**. Never assume the design works; instead, obtain concrete feedback by writing code to determine if it does in fact work.
- **Feedback is your friend**. Expect to receive feedback about work and be prepared to consider it and act accordingly.

- **Sometimes the simplest tool is a complex CASE tool**. When it comes to requirements, then inclusive tools that developers tend to lean on are sophisticated tools which (re)generate code.
- **Iterate, iterate, iterate**. With an iterative approach to development someone works a bit on requirements, analysis, design, coding, and testing and iterate between these activities as needed. A developer may also iterate back and forth between working on various artefacts, working on the right artefact at the right time.
- **Design is so important to be done every day**. It is critical to think through how a developer is going to build something, i.e. to actually design it before building it. Design efforts may take on the form of a sketch on a whiteboard, a detailed model created with a sophisticated modelling tool or a simple test that they write before they write business code. Agile developers realize that design is so important that they do it every day. For agile developers, design isn't just a phase that they do early in the project before getting to the "real work" of writing the source code.
- **Design for a specific implementation environment judiciously**. Developers must take advantage of features of the implementation environment. Trade-offs are normal, but developers must understand the implications and manage the risks involved. Every time a developer takes advantage of a unique performance enhancement tool in a product, such as a database, operating system, or middleware tool, he or she is likely to couple the system under development to that product and, thus, reduce its portability, namely the ability to execute the product on different software platforms. To minimize the impact of the implementation environment on the system under development, the developer can layer the software and "wrap" specific features to make them appear general to users.

- **Document complicated parts of the code**. If a part of the code is complicated, then it is better for the developer to document it thoroughly. Better yet, the developer should invest the time to design it so it is simple.
- **Do not over documen**t. A developer needs to document their design. However, users pay to build systems, not to document them. There is a fine line between under documenting and over documenting, and only through experience this can be understood.

6.7 The lean design philosophy

Not far at all from the principles of agile design philosophy comes lean manufacturing or lean production that constitutes a systematic method for the elimination of waste (“muda”) within a manufacturing system. Lean also takes into account waste created through excessive burden (“Muri”) and waste created through unequally balanced in workloads (“Mura”). Womack et al. (1990) and Womack & Jones (1996), argue that Lean production systems have been around in industrial manufacturing processes for many years but only recently they have also been appreciated by service industries as well. The following key aspects mainly describe lean systems:

- **Precise value** by specific product and its redefinition and re-evaluation through the eyes of the customer.
- Identification of the **value stream** for each product, with a distinct reference to the entire chain of actions that are required in order for a product to be delivered to the customer from its raw materials.
- **Successful flow** without interruptions, which means that there is always a constant and on-going flow, leading to a cost effective, high quality end product and a reasonably short lead-time.
- **Just-In-Time (JIT) methodology** that offers the opportunity to the customer to pull actual value from the producer and fulfil what he/she

requests it rather than relying on a not so accurate forecast of potential sales.

- Strive for the absolute **perfection and constant improvement** rather than attempt to be better than the competitors.
- Organization based on close co-operation with suppliers and empowerment of the workforce.

Lean manufacturing focuses on what adds value, simply by reducing every other “useless” feature within the production line. This management philosophy was first conceived by the Toyota Production System (TPS) and identified as "lean" during the 1990s, consequently, the steady growth and transformation of Toyota from a small company to a world-class automaker industry, has raised attention on how it has achieved this success.

According to Toyota, there are three types of deviation from optimal allocation and management of resources and these are wrapped in the aforementioned terms of “Muda”, “Muri” and “Mura” that have their roots in the company’s Production System tactics:

- **“Muda”** is a Japanese term that implies "uselessness” and constitutes one the three types of deviation from optimal allocation of resources. Profit can be effectively pursued only through the reduction of waste while muda describes any process that consumes more resources than needed and eventually leads to waste. Generally, there are two types of Muda, namely **Muda Type I** (activity with no added value but necessary for end customer) and **Muda Type II** (activity with no added value and unnecessary for end customer but aims to eliminate waste). Toyota Production System identifies the wastages that occur and group them into 7 major categories such as **overproduction** (production ahead of demand), **transport** (moving products that are not actually required to perform the processing), **over processing** (resulting from poor tool or product design creating activity),

waiting (waiting for the next production step, interruptions of production during shift change) **inventory** (all components, work in process, and finished product not being processed), **defects** (the effort involved in inspecting for and fixing defects), **motion** (people or equipment moving or walking more than is required to perform the processing). Even though this seems like an almost complete list of Muda, an eighth type was added by Womack et al. (1996) and it refers to manufacturing goods or services that do not meet customer needs and/or specifications.

- **“Muri”** is a Japanese word as well and it refers to many concepts such as "unreasonableness”, “beyond one's power”, “by force”, “compulsorily”, “excessiveness”. Standardized work that will assure effective judgment of quality is all that is needed in order to avoid Muri. Every function and process should be reduced to its simplest elements for examination and later recombination into standardized work sequences. In manufacturing, this includes logical directions to be taken and continuous work flow.
- **“Mura”** implies "irregularity” and “inequality” as well as “lack of uniformity”. Mura, in terms of business and process improvement, can be avoided through Just-In-Time systems that are based on keeping little or no inventory. These systems are able to supply the production process with the right part, at the right time, in the right amount, creating a “pull system” in which each sub-process withdraws its needs from the preceding sub-processes, and ultimately from an outside supplier. In case a preceding process does not receive a request or withdrawal it stops producing more parts. This type of system is designed to maximize productivity while minimizing storage overhead.

The lean philosophy (lean thinking, lean manufacturing) or Toyota Production System were developed by the Japanese in the mid 50’s, and is nowadays worldwide used by companies. The term lean thinking encompasses

a set of lean practices the popularity of which has spread significantly until the present day. Although earlier lean applications only focused on manufacturing companies (this is why they are widely known under the terms “lean manufacturing” or “lean production), lean thinking philosophy has moved quickly to new contexts such as trade, services and the public sector, however its major use is still spread among other areas.

The core concept is how to maximize customer value while minimizing waste or, even better, how to create more value for customers with fewer resources.

In order to deliver this, lean thinking shifts the focus of management from optimizing separate technologies, assets and vertical departments to optimizing the flow of products and services through entire value streams that flow horizontally across technologies, assets and departments to customers and need less human effort, less space, less capital and less time to make products and services at far less costs and with much fewer defects compared to traditional business systems. In addition, companies are able to keep up with the demand and respond to changing customer desires with high variety, quality, low cost and most importantly very fast. One more positive aspect of lean production is that makes management data much simpler and more accurate.

According to Karlsson, et al. (1995) and Ahlstrom (2004) within the manufacturing industries there are seven characteristics that define lean manufacturing:

- Elimination of waste.
- Zero defects or do-things-right-first time.
- Pull instead of push.
- Multifunctional teams.
- Decentralization that implies distributed and shared responsibility and decision making.

- Vertical information systems.
- Continuous Improvement.

6.8 The principles and success factors of lean manufacturing

As previously mentioned, lean methodology and philosophy, maybe thanks to the fact that was first conceived and implemented by Toyota (Production System) has straight and strong connections with manufacturing processes and environments as well as with industrial assembly-production lines that, especially today, are characterized by short production cycles and impressively reduced batch sizes. On the other hand, the variety of product types and models that can be addressed through lean production processes tends to increase. Constant pressure to shorten lead times adds to such demand and makes the combination extremely challenging.

The necessity to quickly respond to the rapid and often unpredicted customer demands requires the existence and deployment of manufacturing systems that can be re-configured and expanded on the fly, and which can accommodate advances in assembly techniques and eliminate large capital outlays for dedicated machinery without making any initial manufacturing investments obsolete and, most of all, costly. It goes without saying that lean manufacturing is an approach that depends greatly on workplace organization and maximum use of personnel and flexibility.

The concept of lean manufacturing leads to a gradual departure from the automated factory processes that have been extremely popular so far. The approach of manufacturing simplicity leads to uncluttered environment that responds perfectly to the manufacturer’s demands and expectations. This means that products are manufactured in smaller amounts according to the customer’s requirements rather than in big batches since the main objective is to produce only the quantity required and no more.

The lean manufacturing approach should not be considered as the solution in every case and for all manufacturing needs. It does, however, offer a

uniquely effective solution for assembling more complex products since it is based on 9 basic manufacturing principles:

- Lean machines / simplicity.
- Continuous flow.
- Parts presentation.
- Workplace organization.
- Maintainability.
- Reconfigurability, product quality.
- Ease of access and ergonomics.

In addition, the wide range of factors related to the successful implementation of lean manufacturing, could be summarized into the following:

- Development of organizational readiness.
- Development of organizational culture.
- Management commitment and capability.
- Providing adequate resources to support change.
- Strategic approach to improvements.
- External support from consultants when/if needed.
- Effective communication and engagement.
- Development of teamwork thinking.
- Timing to set realistic timescales for change and to make effective use of commitments.

6.9 The 5S of LEAN

As previously mentioned, the lean philosophy aims to reduce costs while it tends to improve and optimize performance. The most common approaches

that companies adopt in the stage of making their organization leaner, are Value Stream Mapping (VSM) and 5S.

5S is the abbreviation of a workplace organization method that makes use of the following five japanese words: shitsuke, seiton, seiri, seiso, seiketsu These five words, transferred into Roman Script all begin with the letter "S" and they actually describe the way to organize a work space in an efficient as well as effective way by identifying, storing and maintaining the tools and items used in order to sustain the correct order and usability.

Even though some lean practitioners consider 5S a tool or methodology, in reality it seems that it is more than that. It can be argued that it is related to a culture and a set of practices that have to be implemented into any organization, which aims for continuous improvement of working conditions and working environment. 5S should seriously involve everyone in the organization from the top level to bottom. In addition, 5S shouldn't be considered a mere list of action items that has to be reviewed in between time, instead, it has to be implemented regularly as a daily practice and activity, which requires concentration and dedication for supporting it and making it evolve in a company-wide culture. The Japanes 5S can be translated in English as sort, set in order, shine, standardize and sustain.

Figure 1. The 5S of Lean.

"Sort" (Seiri) is about sorting through the contents of the workplace and removing unnecessary items. This is an action to identify and eliminate all unnecessary items from the workplace and consequently leads to:

- Making work easier by eliminating obstacles.
- Removing waste and preventing accumulation of unnecessary items.
- Evaluating necessary items with regard to cost or other factors.
- Removing all parts or tools that are not in use either from the workplace or from storage.
- Defining an area where to place unnecessary items that cannot immediately be disposed of.
- Disposing the aforementioned unnecessary items when possible.
- The need for a fully skilled supervisor for checking on a regular basis.

"Set in order" (Seiton) is putting the necessary items in their place in order to ensure easy access. According to this action every necessary item is put in good order and emphasis is put on efficient and effective storage methods that result in:

- Preventing loss and waste of time by arranging work station in such a way that all tooling / equipment is in close proximity.
- Arranging all necessary items so that they can be easily selected for use.
- Maintaining safety.
- Making it easy to find and pick up necessary items and components according to their uses, with the frequently used components being nearest to the work place.
- Ensuring first-in-first-out asset management.
- Making workflow smooth and easy.

"Shine" (Seiso) involves keeping everything clean daily and using cleaning to inspect the workplace and equipment for defects. As a consequence:

- A cleaning frequency should be clearly set.
- Preventing machinery and equipment deterioration is a priority.
- Workplace ought to be kept safe, easy and pleasant to work in.

"Standardize" (Seiketsu). This is the fourth step of the 5S method and it involves creating visual controls and guidelines for keeping the workplace organized, orderly and clean. Seiketsu enables and ensures compliance to the new standards of cleanliness. The benefits include:

- Maintaining the higher morale gained during Seiso.
- Pride in the workplace.
- Relapsing into dirty or messy conditions means that the Seiso effort was wasted.
- Minimal investment in time: 5 minutes per worker per shift.
- No big clean-up before a visit from customers or executives.
- Less downtime for equipment.

"Sustain" (Shitsuke). This is the fifth and final step of the 5S method. It means "sustain" or "sustained discipline" in order to ensure that everyone follows the 5S standards. This is a condition where all members practice the first four S’s spontaneously and willingly as a standard way of acting. “Shitsuke” is a Japanese word that carries a wealth of cultural meaning such as:

- Discipline and training imposed upon a person.
- Self-discipline.
- Shared cultural self-discipline.
- Personal discipline to continually practice and improve.

Figure 2. Correct arrangement of tools according to 5S standards.

7. THE EVOLVING LANDSCAPE OF TEACHING AND LEARNING IN HIGHER EDUCATION INSTITUTES (H.E.I.)

7.1 The challenges driving innovation in teaching and learning

In order to meet the objectives of the Europe2020 Strategy, central role to higher education has been assigned by the European institutions thus the European Commission (EC), from 2011 to 2013, has stressed the crucial role of education and more specifically that of higher education as a key factor that can potentially facilitate smart and sustainable growth and socio-economic development. According to Guri-Rosenblit et al. (2007) this is partly reflected in the trend of the expansion of higher education worldwide during the last 50 years and is expressed by actual figures such as the leap from roughly 32.5 million students enrolled in higher education worldwide in 1970 to 178 million in 2010 as estimated by the UNESCO Institute for Statistics (UIS). Furthermore, according to the British Council (cited in Davis, 2003 and Daniel, 2009), the number of higher education students is bound to further expand and reach 263 million by 2025.

There are good reasons for the aforementioned “revolution” such as the increased public demand for higher education, further democratization, independence and urbanization processes and movements in the developing world as well as the shift towards post-industrial economies that demanded highly educated workforce as a prerequisite of economic development. In addition, as Schofer & Meyer (2005) and Altbach (2009) argue, fast technological change has further stimulated access to higher education which resulted to higher participation rates.

According to Naidoo (2003), higher education is a crucial sector for the production, dissemination and transfer of economically productive and innovative knowledge and technology in today’s economies. What is of particular interest is the concentration on the close connection of higher education

institutes with other institutional “ecosystems”, such as government and non-government agencies, industry and the society at large. The main challenges that the higher education sector faces, not only in Europe, and that are expected to drive innovation in this field are the always transforming demand for higher education, the pressures that stem from globalization and, last but not least, the changes in higher education funding that shift the priorities and call for immediate solutions. For these reasons, design and implementation of various innovative practices to address such critical issues are of high priority but at the same time the establishment of innovation in higher education systems might have a significant impact on a wide range of direct and indirect, individual and institutional actors either at the relationships level regarding networking, mobility and collaboration or on the research and engagement functions and practices.

Carlsson et al (2002) argue that the main function of an innovation system is defined as the production, diffusion and utilization of technology and in that sense the spectrum of central functions of higher education in the new era could be identified with providing education, undertaking research, and promoting community engagement and entrepreneurialism. Following this vision, one of the most critical aspects of innovative teaching and learning in University is the changing supply of and demand for higher education and for this reason, Institutions should consider the need to:

- Identify the actual and diverse needs and circumstances of the learners, the rapidly changing expectations of students, including lifelong learning, flexible and alternative ways of learning, along with the skills sets they have already acquired in the use of new learning technologies. According to OECD (2008), learners seek to acquire particular knowledge or skills to satisfy specific market needs thus they prefer to “cherry-pick” courses from various suitable providers rather than follow a “traditional” course at one institution.

- Ensure students have access to up to date, innovative tools, technologies, methodologies and processes that respond to individual student needs and further develop their learning and secure the possession of all the necessary skills that will allow them to gain maximum educational benefits.
- Recognize that the successful involvement of various actors, namely academics, researchers, businesses and, where applicable, employers effectively supports and enhances students' prospective careers.
- Clarify the roles of the aforementioned different actors within and beyond their institutions and ensure a collective understanding of their contribution and relationships between them.
- Exploit in their course design processes, the changing needs and expectations of employers and of the labour market that the students are expected to enter upon graduation.
- Integrate and advance new technology in a rapid way as technological advancements have and will continue to have significant impact on the organization and provision of higher education (Johnson et al., 2014). Taking full advantage of the educational opportunities provided by ICT helps expand student access to education and at the same time improve learning outcomes. As of now, internet-based instructional delivery happens to be a rapidly growing pedagogy within higher education in many countries and this has already widened the perspectives for even greater opportunities while at the same time it has introduced new challenges.
- Consider seriously the fact that recent advances in data collection and analytics have offered additional opportunities to monitor and track student learning, individually and in the long term (Garcia & L'Orange, 2010). Such advances in data analytics give way to the successful identification of potential obstacles and blockages that

students encounter during their studies. They offer considerable support for conducting formative assessments of learning and the outcomes can be helpful to both students and instructors.

- Take full advantage of higher education internationalization processes. One of the pivotal and key transformations of higher education in the past 25 years, as a response to increasingly inter-connected world economy and to growing demand for internationally recognized qualifications and skills, has been the wider opening of universities and research institutes on a global scale through internationally organized activities, exchanges and mobility actions which are, by now, an essential dimension of national and institutional strategy and policy (OECD, 2008). Building international profile status is also important for universities and their students because in the context of the “new economy” employers in OECD countries seem to face the need to increasingly look abroad for talented graduates, as those in their countries are insufficient to replace the ones that go into retirement. Internationalisation has thus become a part of a longer term skill development strategy.
- Consider the increasing pressures on costs and new modes of financing and this is because reforms of higher education finances over the past 15 years have focused on three main directions, although the relative importance of each depends on the specific country (OECD, 2008). First of all, funding sources have changed and this partly reflects a universal trend of shifting running costs to students and away from public funding sources through greater contributions by students and their families by means of higher fees. Private resources have also been mobilized through the commercialization of research and other private uses of institutional facilities and staff. In addition, the allocation of public funding for tertiary education has be-

come more output-oriented. In a number of countries, formulas to allocate public funds to HEIs are now related to performance indicators such as graduation or completion rates.

7.2 The importance of innovative practices in higher education teaching and learning

It is widely recognized that the acquisition of skill and human assets has become the factor that drives economic prosperity and social well being nowadays. Global economies and societies are knowledge oriented and intensive and significantly influenced by technological advances. Thus, countries need to disseminate knowledge, develop and sustain a highly skilled workforce and maintain a competitive research base in order to retain their competitive edge. Higher education institutes hold a very important role; they represent a major factor in innovation and human capital development and play a central role in the success and sustainability of the knowledge economy (Dill and Van Vught, 2010). This is why the discussion about higher education has gained significant prominence in the framework of national agendas and has triggered profound reforms worldwide over the past decades (OECD, 2008). Altbach et al. (2009) argue that “an academic revolution has taken place in higher education in the past half century marked by transformations unprecedented in scope and diversity”. A significant remark that has to be done is that while almost half a century ago, higher education essentially referred to the traditional research universities that were oriented towards the “elite classes” of the population, nowadays, higher education institutions are more diversified and are characterized by massive expansion and wider participation.

Conventional assessment methodologies in higher education are increasingly under the spotlight and it is uncertain in certain circles if traditional methods are in fact as effective as they are believed to be. Since the quality of education is critical to a nation’s success it is important to interrogate a number of strategies and methods. The application of innovative teaching

and learning methods is critical for motivating and engendering a spirit of learning as well as enthusiasm on the part of students, for learning while enrolled in higher education programs and indeed for lifelong learning. The role of education is to ensure that while academic staff does teach, what is taught should also be intelligible to students emanating from culturally and linguistically diverse backgrounds and that they rapidly become familiar with the expected standards. It is more often than not the case that students underachieve because of the fact that they have not grasped an awareness of the level of assessment or what it is that the lecturer expects from them. Lecturers should thus apply themselves to utilising innovative methods so that the students' learning process is as free-flowing as possible and that the methodology they adopt is conducive to learning. Innovative teaching and learning methodologies such as short lecture, simulation, role-playing, portfolio development and problem-based learning (PBL) are very useful in addressing the rapid technological advances and developing workplaces that will be required in the foreseeable future.

8. NATIONAL POLICIES, PRACTICES AND STRATEGIES REGARDING THE LINKING OF HIGHER EDUCATION TO INDUSTRY

Within the landscape of a rapidly developing economy and in line with an impetus from the EU expressed through its operational programs, higher education institutes and Industry need to establish direct links for substantial cooperation or intensify the existing ones by gearing them more effectively towards innovation, “fresh” business start-ups and knowledge transfer and dissemination. Industry of the modern and ever changing globalised economy is absolutely linked with its potential to increase productivity through process innovation, which itself depends on the “production”, implementation and transfer of new knowledge that, in turn, is generated thanks to the academic research efforts. New ideas and knowledge that remain separated from innovation and actual use in the field of the real market are substantially worthless. In addition, since governmental funding has shrunk to insufficient levels, higher education institutes clearly can’t afford to ignore this aspect. Therefore a fundamental change of attitude from both sides and the generation of modern schemes of cooperation, attractive both for the industry and for universities are much needed in order to effectively face the always-increasing complexity of emerging economic mechanisms. Observing and registering university and industry cooperation models in the countries that are involved in LEAP project is reserved to the following section of the report.

8.1 In Greece

Regarding the link between universities and industry in Greece cooperation as well as research and innovation promotion are expressed and implemented in various forms, namely, joint programs, improvement of academic infrastructures, establishment and operation of new departments that are focused on new market trends, research projects, internships, seminars and

so forth, all this partially aided by European funding. Through such structures and initiatives that aim to support collaboration between higher education institutions and industry and stress good practices one more effect that comes to surface is the re-assessment and re-establishment of the concept of innovative entrepreneurship. In other terms, this means a change in mentality and policies that will help the universities and their students to face the evolving market, the industry and the profession as a source of constant evolution, new objectives, significant funding and, generally, as a starting point for personal/collective fulfilment and opportunities. Through the years, all this was to be achieved through the following actions:

- **Liaison & Technology Transfer Offices (LTTO) and Career Offices (CO)**. Liaison Offices/Career Offices can be considered relatively new in the ecosystem of Greek higher education institutions since they made their appearance for the first time in the early 1990s and thanks to significant funding almost every university hosted their valuable service, which, has expanded through a wide range of activities, aimed at supporting students and alumni in their effort to successfully enter the labour market. As of today, the services offered by the Liaison & Career Offices appeal to a wide audience, which extend from students, faculty members and researchers to enterprises, chambers, employers' organizations, etc. They further extend to an even wider community, comprising of students, parents, secondary education counsellors and so forth. One of the specific objectives that justified the installation of LTTO and CO within the activity of local universities was to finally strengthen the human research potential especially through the enhancement of the quality and effectiveness of higher education as well as through the support of research and innovation and the networking of universities with the business world and research institutions in a way that this could significantly improve the competitiveness of the Greek economy. Among the services they usually offer are continuous documentation

and dissemination of information regarding contacts with local businesses that seek collaboration with the university, organization of seminars, handling of requests for co-operation, counselling and support, workshops, networking with other Liaison Offices in Greece and abroad, with local authorities and other bodies and the dissemination of calls for participation in programs and funding schemes. Furthermore, LTTO and CO contribute actively to the organization of dissemination events that help the establishment of relationships with nearby universities and research institutes, such as the well-known and successful, so far, “Researchers’ Days” and “Local entrepreneurs’ Days”. In addition, LTTO provide help regarding legal issues and advice (Licensing, Copyrights and Trademarks, Patents, Confidentiality Agreements, Technology transfer agreements and so forth) and support the continuous documentation of active research laboratories and the exploitation of any research outcomes in a way that they can potentially attract wider interest and find appropriate funding for further development and commercial use.

- **Apprenticeship and Practical Training Offices**: The offering of apprenticeship opportunities is considered a quintessential part of the educational processes in universities as it establishes a first contact between students and the labour market and it helps students to put in actual use any theoretical knowledge acquired during the formal courses. In other words, it helps students establish links between theory and practice. The actual and real-time application of knowledge in the labour market can assist the development and orientation of entrepreneur-graduates. It potentially pumps the creation of new jobs and drives creativity and productivity in a way that constitutes apprenticeship opportunities highly sought after not only by institutions but also from labour market and businesses (Kaltsogianni et al, 2014).

- **Innovation & Entrepreneurship Units**: Even if the links between innovation and entrepreneurship are highly acknowledged in Greece higher education institutes have hardly directed their students towards entrepreneurship actions. Given that, there has been a serious attempt aided by the National Strategic Reference Framework (2007-2013) and in particular the Operational Program “Education and Lifelong Learning”, which fostered the establishment and operation of various innovation and entrepreneurship units in most higher education institutes (Xenos, 2011). Such units focus on the implementation of various activities such as the dissemination of entrepreneurship workshops, the development of educational material regarding entrepreneurship, visits to businesses and other organizations associated with effective practices and acting as role models, seminars for entrepreneurs and business executives, open discussion and round tables on the development of business ideas and business plans and last but not least counselling and mentoring through networking.
- **Science Technology Parks:** The IASP (International Association of Technology Parks), argues that the institution of Science Technology Parks (STP) should be considered as an initiative with strong links with Universities and Research Institutes, since it was conceived and materialized in order to encourage a blend of creative, knowledge-intensive businesses housed on site and largely based on the direct transfer of technology, entrepreneurship principles and local development from a team of experts or a university to the real market without the time-consuming and mostly unnecessary “middlemen” and intermediate procedures. The first STP that ever appeared in Greece thanks to the initiative of the Foundation Technology Hellas (FORTH), was the Science and Technology Park of Crete (Heraklion) in the early 90s, while shortly after more Science Parks were established in Patras, Thessaloniki, Athens ("Leucippus" was created by the NCSR "Demokritos") in Lavrion (Cultural Technology Park by

NTUA), in Volos (Thessaly Technology Park) and in Ioannina. According to Kaltsogianni et al (2015), all the existing STP in Greece are the fruit of government initiative and collaboration between research and academic institutions and the General Secretariat of Research & Technology.

8.2 In Estonia

In the new strategic planning period 2014-2020, Estonia has set some areas related to engineering and industry practices. However, entrepreneurship and development of new products and services is related with engineering are not related with each strategy:

- **Estonian Entrepreneurship Growth Strategy 2014-2020** promoting entrepreneurs and development of new products and services. The strategy targets government demand through public procurements for promoting innovative products and services.
- **Start-up Estonia program** focuses on supporting development of learning modules about entrepreneurship, spin-offs and interdisciplinary approaches using the agile development methods and minimum viable prototypes. Entrepreneurship competences must be integrated to different curricula using gamified and interactive methods in teaching science and engineering subjects involving entrepreneurs to teaching process.
- **Estonian lifelong learning strategy 2020**: promoting lifelong learning, human resources, and competences. Among 5 strategic goals, the changed learning approach is one that should develop creativity and entrepreneurship at all levels and types of education. In vocational and higher education the changes will be directed towards self-directed active learning, practicing and formative evaluation. One of the targets is quality level engineering education and particularly its relatedness to practice.

- **Strategy Smart and active nation 2015-2018** targets more researchers and engineers.
- **The Research and technology Pact 2015** integrates different stakeholders in research, engineering and technology to education with the objective of enabling and promoting careers. It raises the quality of engineering at all levels and kinds of education, e.g. relating different curricula to interdisciplinary modules, developing flexible learning paths, using commonly the labs and learning resources, developing motivation packages for students, involving employers, enterprises and teaching clusters.

8.3 In Spain

The Spanish Constitution “recognizes the autonomy of Universities, in the terms established by law” in article 27.10 (Constitución Española, 1978). In this sense, the universities can resolve the subjects for the curriculums. Current Spanish legislation on universities starts with the Organic Act 6/2001 of December 21st, known as LOU (Ley Orgánica de Universidades), which is modified by the Organic Act 4/2007 of April 12th, which stresses in taking the university as an autonomous, self-governing corporation. Besides, it establishes the ordinance of official higher education, specifying the structure according to the European Higher Education Area (EHEA) providing a first adaptation to the Bologna Process.

In relation to linking knowledge, skills and competencies developed engineering higher education to industry practices, Royal Decree 1939/2007 introduced a new strategy missing in previous legislation: internships in external companies. Those allow the students to test their knowledge and skills in a real working situation as part of their academic training, with a limit of 25% of the maximum ECTS (European Credit Transfer System) of the degree, according to the last modification of the Royal Decree 43/2015 (origi-

nally, the maximum was defined in 60 credits). This way, external internships count as academic training and are measured using the same unit adopted for normal theory and practice class hours: ECTS.

The legislation defines in the so-called White Papers how to detail the degree programs in terms of competencies to be developed in general and for each subject. However, it does not define the degrees, the actual competences to be developed, the subjects to be taught or the methods to teach. The design of the degrees adapted to the EHEA is currently carried out by the ANECA Network formed by a group of universities and the National Agency for the Evaluation of Quality and Accreditation (Agencia Nacional de Evaluación de la Calidad y Acreditación, ANECA). This agency is an autonomous body attached to the Ministry of Education, Culture and Sport, created in 2014 (Law 15/2014) and whose mission is to guarantee the quality of the Spanish Higher Education System contributing to the consolidation of the EHEA. The result of the design of the degrees is reflected in the White Papers published by ANECA, which define the structure of each degree, the competences to be developed and the subjects to be taught. Each White Paper is specific to a degree. In the White Papers dedicated to engineering (telecommunications, information and computer science) very few make direct references to agile and lean methods.

In the Telecommunication Engineering White Book (ANECA, 2004), despite being oriented towards the preparation of engineers for professional practice there is no specific reference to agile or lean methodologies. However, general competencies aimed at the practical exercise of the profession are defined, such as “ability to work in a team” or “ability to design a system, component or process in the ICT field to meet the required specifications” and competences specific to each practice-oriented specialization. In addition, some subjects related to project development and oriented to professional practice are defined within each specialization, as shown in the table below:

Degree	Subject	Content	Credits
Degree in Electronic Engineering	Project	Methodology, definition and elaboration of projects	3
Degree in Telematics Engineering	Project management	--	Together with business economy and legislation, between 10 and 13
Audiovisual Systems Engineering	Programming	Methodology, data structures, algorithm and languages	10
Audiovisual Systems Engineering	Audio/video/multimedia projects	Direction, cross-disciplinary teams, planning, audiovisual production, sequencing, cost, work tracking, distinctive features of audiovisual projects	6

Table 1. General competencies aimed at the practical exercise of the profession of engineer.

In addition to these subjects, the White Paper recommends that the Final Degree Project include a minimum of 15 ECTS of supervised practices in a company of the sector (450 hours) for the Electronic Engineering Degree. The remaining degrees are not given a credit number recommendation, but they include optional internships in companies as part of the academic training.

Moreover, the Computer Science White Book (ANECA, 2005) does not contain any reference to agile or lean methodologies despite being oriented to the preparation of the engineer for the professional practice. However, throughout the book we can find features, competencies and goals directly related to them, as we will see next. The professional profile for software

development includes Project Management ("defining project goals, assessing needs and resources, estimating tasks and development work, establishing milestones and detecting critical points and planning") and Software Quality Management ("quality planning, validation, verification and control of activities, product metrics and process attributes, and reliability and dependence on software"), which are directly related to agile methodologies.

In addition, among the competencies defined for this degree there are project management and planning, software engineering, and methods and tools for the design and development of software-based systems. In particular, the software development profile specifies the relevance of the ability to "manage and coordinate the project development and maintenance of applications" and "dominate all stages of the life of a project (design analysis, technical analysis, programming, testing, documentation and user training)". The transversal competences of all IT engineering profiles include "supervising, controlling and validating development processes". Again, no mention is made of agile methodologies. Among the objectives of the Computer Science Degree, one of the six key points is "having the skills required in professional engineering practice: being able to manage projects, communicate clearly and effectively, work in and lead cross-disciplinary teams, adapt to changes and learn autonomously throughout their lives", which is materialized in the common training content, within the subcategory Professional Skills.

It should be noted that in the distribution of content, the number of credits for practical skills prior to the publication of the White Book varied enormously from one university to another, namely between 7.8% and 51%. The content geared to management and communication skills received between 0% and 22% of credits.

The realization of internships as part of the training is not explicitly included in this book, although it is recommended "universities, to the extent of their

possibilities and their autonomy, facilitate students the possibility of practicing in the business sector for a minimum period of three months". The report also emphasizes that business internships are compulsory in countries such as Germany (one full semester) or Finland (minimum 20 ECTS), which serve in this case as a reference.

The Industrial Engineering White Book (ANECA, 2006) does not contain specific references to the lean methodology or the Kanban system. In addition it vaguely treats the competences needed to obtain the title in industrial engineering, providing a simple enumeration. In any case, there are related competences for several degrees included in the book:

- Master Industrial Engineer: project management and development in all industrial fields; technical management and project management in industrial plants and companies.
- Mechanical Engineer: manufacturing techniques and production organization; writing and analysis of technical documentation, process improvement.
- Industrial Automation and Electronics Engineer: design of automatic and electronic control systems to improve industrial processes, services, or to develop new products.
- Industrial Design Engineer: design, project and marketing of products.

The degrees of Industrial Technologies Engineer, Electrical Systems Engineer and Chemical Engineer do not have any competence related to the lean or agile methodologies in the description provided in this book.

In the aforementioned book, three qualifications are considered separately as degrees, instead of master degree (Degree followed by Master according to the Bologna Process): Industrial Organization Engineer, Materials and Energy Engineer. The former is directly related to work methodologies,

given the specific competencies of the degree, of which we highlight five of the seven defined in the book:

- Propose innovative ideas and alternatives for the improvement of productive and organizational systems.
- Identify new techniques and tools for the organization and management of companies.
- Manage the experience and knowledge of the members of the organizations in order to obtain functional improvements.
- Plan and manage production, logistics and administrative systems.
- Design, implement, evaluate and manage quality systems.

Proyecto Universidad Empresa (PUE) is an important company for the technological dissemination and update of formal education teaching staff. It manages the academic projects of multinational companies in the information technology sector. It was founded in 1998 with the aim of bringing the required knowledge in the workplace to technical education. Since then, PUE participates in the different phases of the training process: teacher training, management and assignment of educational projects, provision of equipment, licenses, teaching materials and management of the issue of certificates. They currently have their own SCRUM training project called the SCRUM Manager Academy.

Considering the autonomy that the universities have by law and that the programs established by ANECA do not define the contents or the subjects but the competences, it is universities' responsibility to define them. More specifically, the departments of each school, specialized in the subjects to be taught, are the ones that define the program of each subject according to the required competencies. Thus we find some learning projects based on lean and agile methodologies in several Spanish universities:

- The teaching project for the subject "Software Engineering I", presented in (Goñi et al., 2014), followed the methodology of Project-

Based Learning (ABP) using agile methodologies, specifically SCRUM. The approach followed is essentially practical, minimizing the number of theoretical hours. In this project, the students tackled in groups a project in several “sprints” of four weeks. For each sprint, the students were given a defective or unfinished work to complete, having to meet a set of specifications defined previously. In this way the students were introduced to the methodology, including the working procedures and documentation, having to generate the deliverables of analysis, design and implementation corresponding to each sprint and the project as a whole. This initiative, which started in 2012, has been revised year after year and continues until today at the University of the Basque Country.

- At the Universitat Politècnica de Catalunya (UPC BarcelonaTech), SCRUM has been introduced in the subject “Application Engineering”, which belongs to the Degree in Telematics Engineering and follows a Project Based Learning (PBL) approach (Arcas et al., 2015). In this subject, the students have to develop a project applying the theoretical knowledge that they are learning, following the SCRUM methodology rigorously. In each project, the product owner is the teacher and the students are grouped in development teams. In each sprint, one of the students in the group will be the SCRUM master. The SCRUM master is in charge of managing the product list. Because of using part of the face-to-face classes for the SCRUM events, there is a slight cut in theoretical knowledge acquired in class, which must be compensated by the students with hours of personal work and autonomous learning. According to the results of this project, SCRUM brings benefits to the PBL methodology, for example, improving the learning process of the students, monitoring the projects during the course or increasing students’ motivation.
- At the University of Granada, SCRUM was introduced in an agent-based programming course to foster awareness of the development

process and to enforce cross-curricular competencies, especially self-organised teamwork, planning, use of time, and leadership (Castillo, 2014). They followed the SCRUM methodology to develop different assignments (product), each one in a sprint. The roles and the procedures were the same as in the later example. They achieved great results for all the teams but one, which was unable to recover after one of the students left the team.

8.4 In the U.K.

Progress in achieving deeper and more effective collaboration between employers (industry) and universities (academy) in educational provision has been slow. Obstacles include the complexity of the education system with different providers offering skills at different levels as well as the difficulty to offer the incentives for employers to provide sufficient resource towards the cost of providing graduates with the skills they really need. Furthermore, in the U.K. especially in the post-Brexit era, the design of a sound industrial-educational strategy is a critical part of the country's financial plan as it is expected to deliver a stronger economy that will secure wealth and equal opportunities even far from centrally located and prosperous places such as London and the South East. According to the Industrial Strategy Green paper (HM Government, 2017) this plan is expected to help young people to develop the skills they need in order to pursue high-paid and high-skilled jobs of the future as well as create the conditions within which successful businesses will emerge and grow gradually. In this context, one of the challenges that the UK has to face is to address:

- Either the issue of more individuals going to university than ever before as too many young people seem to lack the education and skills they need in a modern economy.
- Or the building of a new system of technical education to benefit the half of young people who do not attend university for various reasons.

It is widely known that the U.K. has some world-class universities and a large proportion of the population have degree level qualifications although technical education has been relatively neglected, consequently, there is a significant shortage of technical-level skills or particular skills shortages in sectors that rely on STEM subjects which brings to the need to create the right institutions to support development over the long term or to enforce the already existing business-led institutions.

One of the planned steps is straight collaboration with local areas' structures in a way that it will help develop industry clusters based around local expertise and local R&D and educational institutions. According to the plan, this involves creating new institutions or strengthening the role and function of the existing ones such as educational and innovation institutions, business networks and trade associations, or financial networks and local funds.

Some of the most important steps towards the integration of industry practices and collaboration in higher and technical education Institutions in the UK can be summarized in the following:

- **Identification of sector-specific skills gaps** as it has been recognized that previous efforts by the government and industry to forecast skills shortages have failed to take effective and accurate action. Part of the problem has been the lack of a single authoritative source and there is a coherent plan from the new government to address this issue.
- **Higher quality careers information and advice**. It is recognized as well that the British education and skills system should be supported by high-quality careers provision. A good start has been made through the investment of £90 million in order to support young people in accessing the needed advice. The Careers & Enterprise Company's Enterprise Adviser Network is already taking action by connecting 1.300 schools and colleges with local employers to provide experiences of the workplace for young people.

- **Employers' active engagement**. A wide spectrum of engagement models that involve employers currently operates throughout UK STEM higher education. These models refer to mere careers advice, information and guidance, contribution to the co-curriculum (contribution of workplace case studies or work-based scenarios), work-based learning through placements and internships or even closer forms of engagement via co-investment in facilities, or partnerships and alliances between individual or groups of employers and universities. In some other cases, more strategic forms of employer and industry engagement involve delivery of programs through contributing to teaching, assessment and the supervision of projects, curriculum design and development and even financial support for students and investment in educational infrastructure.

Most of the aforementioned activity is intended to increase students' employability and there are some examples of strategic links that involve significant commitment, and investment of time and resources, from both partners. Even if not the only ones, highly representative and indicative are the cases of:

- **Coventry University's partnership with Unipart Manufacturing Group** to develop the Institute for advanced manufacturing and engineering (AME). This project brings together experts from the academic world and industry in a live manufacturing environment while it seeks to produce "industry ready" engineering and manufacturing graduates. The partnership involved considerable investment from both sides since Unipart has already contributed £17.9 million towards the partnership and a further £5.6 million towards student scholarships and product R & D.
- **Aston University's strategic partnership with Capgemini** to provide degree-level education following an apprenticeship model, which combines work and study through online learning. Capgemini

oversees the curriculum to ensure that it is industry relevant and employs the students as they undertake their apprenticeship. They also provide case studies and support the practical assessments. On the other hand, Aston University benefits from being able to offer highly industry-relevant courses that improve student recruitment.

- **Sheffield University's training centre based at the Advanced Manufacturing Research Centre (AMRC)**, which offers apprenticeships and degree-level training for companies in the advanced manufacturing sectors. The centre facilitates in-depth collaboration between academy, research and industry by providing technology, expertise and services to the advanced manufacturing sector via collaboration with major employers. It currently hosts major collaborations in the aerospace (Boeing) and civil nuclear energy industries (Rolls-Royce) and companies in their supply-chain.
- **Liverpool John Moores University's partnership with Barclays UK's Strategic Centre of Excellence** to develop a graduate training program. Thanks to this collaboration project, students have become more work ready and have received expert, industry guidance on producing professional applications from engaging with Barclays' staff. In addition, the collaboration has resulted in students being recruited to prestigious graduate training schemes while LJMU academics have been exposed to cutting edge industry practice and Barclays has been able to influence the curriculum to ensure that it is relevant to current working practice.
- **University of Lincoln's strategic collaboration with multiple employers** to develop new schools in STEM subjects. The university has adopted a "co-employer led school" model designed to meet the recruitment needs of different industrial sectors so this way, employers are engaged in developing and managing the new Schools

through specialist advice, co-creating industry focused undergraduate STEM curriculum and providing funding for scholarships and bursaries.

8.5 In Portugal

In Portugal, the link between higher education institutions, companies and industry is not strong. Indeed it constitutes a challenge that is far from being accomplished. Collaborations between universities and industry regarding R&D have decreased between 2008 and 2013, in Portugal, according to the past global competitiveness reports (World Economic Forum, 2013). And this is exactly one of the negative factors associated to Portuguese national economy: the weak university-enterprise link.

Nevertheless, a partnership between the Portuguese state and the European Union has been established with one of its central objectives being the improvement of university-enterprise link. The agreement “Portugal 2020” has as one of the main objectives to bring closer together the universities’ knowledge and scientific system to industry with about 3b Euros to directly support research, development and innovation.

Within the framework of Portugal 2020, a National Innovation Agency was created as the main public entity to address the issue of linking knowledge, skills and competences developed in higher education to industry practices. The agency has already two developed strategies: “Industrial Development Strategy for Growth and Employment Strategy” and the “the National Research and Innovation Strategy for Smart Specialization“ (Governo de Portugal, 2013).

Thus, until 2020 this agency will give priority to some of the following aspects (Governo de Portugal, 2013):

- Experimental and practical-professional components reinforcement and promotion of a greater and better alignment between knowledge

acquired in high education with the knowledge required by enterprises.

- Content enrichment and diversification of the technical training offer in line with the real enterprise needs.
- Raising students and families' awareness regarding the importance of technical training (in all education levels) in order to boost the demand for this type of qualifications.
- Current workers qualification and continuous reinforcement of technical competences.
- Promotion of better cooperation between high education institutions, companies, industry, laboratories and research and technology centres in order to promote innovation and attract young graduates to industry.

A study from Universidade do Minho (Pereira, 2003) addressed the issue of the university-industry link and conclude that, by the time of the study, there was still a minimum interaction between industry and university. By 1999, the expenses made by companies for I&D represented 22,7% of the total R&D expenditures in Portugal and the EU average was 64,7%. Thus, this university-industry link was not very favourable for Portugal, unlike other EU countries, where companies financed a large part of the research and even postgraduate courses.

However, this study is dated from 2003. Today it is possible to mention some examples of entities and universities that have a concern regarding the link between industry and universities.

Ordem dos Engenheiros (Order of Engineers) is a public professional association that represents people graduated in engineering engaged in the profession of engineer. Its main mission is to contribute to the development of engineering, supporting the efforts of its associates in the scientific, professional and social fields, as well as the fulfilment of the rules of professional

ethics. Among other functions the Order assigns the title of engineer; defends the interests, rights and prerogatives of engineers; defends the social function, dignity and prestige of the occupation; enhance their professional qualification and foster the development of engineering teaching (Ordem dos Engenheiros, S.d.).

Specifically regarding engineering high education institutions, there are some specific organisms that promote the link between university knowledge and industry practices. Faculdade de Engenahria da universidade do Porto (FEUP), has a commission for linking university to industry. This commission has as mission to promote and stimulate the like between FEUP and national and international industry, thus supporting the competitive collaboration and search for external resources (Faculdade de Engenharia da Universidade do Porto, S.d.). By making easier dialogue with external organizations/companies, FEUP assures more effective and efficient answers to the research and innovation needs of companies.

Consequently, FEUP develops a series of activities (Faculdade de Engenharia da Universidade do Porto, S.d.) that promote a stronger link between high education engineering and industry in order to:

- Identify FEUP technologies that may interest companies (technology-push) by presenting their possible advantages and by advising companies when incorporating these technologies, so that they have a real competitive advantage.
- Answer to development and innovation needs presented by companies in a demand-pull model. Analyzing competences and technologies best suited for solving problems/needs previously identified in companies. Also collaborate with the companies regarding solutions to adopt and the strategy to follow.
- Promote and make easier the interaction between companies and FEUP through the promotion of individual meetings between enterprises and FEUP researchers.

- Give access to a vast role of information relevant for companies' interests and needs.
- Secure for the companies privileged access to events promoted by FEUP, which offer great networking opportunities with scientific community, entrepreneurs, and international specialists.

Besides FEUP, Escola de Engenharia da Universidade do Minho (EEUM) collaborates with companies at a local, national and international level. By supporting the integration of graduates from EEUM in companies and by collaborating in development, research and innovation projects.Specific activities (Escola de Engenharia da Universidade do Minho, S.d.) promoted in this context are:

- Offering summer and professional internships in companies.
- Projects regarding the thesis dissertation done in a company.
- Projects developed at EEUM that allow the development of a link between specialized knowledge and innovation/developments suggested by industries.
- Promoting activities such as contests, open days, trainees coaching, sessions where companies present themselves and, organizing an employment and a job day, a specific session regarding students' transition to the working world.

According to EEUM, this collaboration creates a spill over of scientific research into innovative products and services that enhance the daily lives of societies and provide business opportunities.

In conclusion, it is possible to understand an increasing concern by Portuguese state to develop strategies that link competencies developed in higher education to company practices in general. In terms of engineering high education some high education institutions have been supporting the development of this link by organizing activities and engaging in university-industry collaborations.

In what concerns emerging learning design, Portuguese high institutions still rely on a methodology in which the teacher mainly worries about the scientific knowledge it transmits to students. Today, interaction and exchange of information between teacher and student, stimulating creativity of students, raising awareness regarding research and innovation should all be aspects a teacher should build in order to benefit and captivate the learners, therefore addressing an active learning methodology (Ramos, A. et al., 2014).

While recognizing the efforts of many Portuguese teachers to adapt their methods to the new demands of the teaching-learning process it is still necessary to reproduce the good teaching practices and generalize the use of active methodologies, thus not only focusing on a passive reproduction of existing information (Ramos, A. et al., 2014).

Even though there is not much systematized information that concerns emerging learning design and especially regarding active learning in Portugal, it is possible to gather the idea that active learning is an emerging tendency in Portugal. Thus, and proving that these learning methodologies are an emerging tendency in Portugal, it is possible to mention a few examples:

- The **Integrated Master Degree in Medicine from Universidade da Beira Interior** has a Problem Based Learning methodology based on practical and multidisciplinary approach in which the student is the centre of the learning process (Faculdade de Ciências da Saúde da Universidade da Beira Interior, S.d.). Thus, this PBL methodology allows the students to have personalized support, at the same time avoids the repetitive and isolated teaching and promotes learning by solving problems.
- **Universidade do Algarve** also applies a Problem Based Learning methodology in some of its degrees. The Bachelor in Information and Communication Technologies integrates theory with practice. This methodology first introduces basic concepts that are essential to understand the issues that are part of each curricular unit, especially in

1st and 2nd year. Then this more traditional approach is gradually replaced by Problem Based Learning methodology as students progress through the degree (Instituto Superior de Engenharia da Universidade do Algarve, S.d.). Besides this bachelor, Universidade do Algarve also offers an Integrated Master Degree in Medicine based on Problem Based Learning (PBL), in which there are no theoretical classes. The teaching of basic and clinical sciences is done only through PBL and seminars. Thus, starting from the 1st year the degree implements clinical teaching. The students are challenged with problems in the form of clinical cases and have to solve them. Classes are also organized in small group tutorials (Departamento de Ciências Biomédicas e Medicina da Universidade do Algarve, S.d.).

- As an additional example of active learning, **Universidade do Minho** introduced Project Based Learning in the academic year of 2004/2005 in the Integrated Master Degree in Industrial Engineering and Management. “In this methodology students have to work in teams to develop, manage, make decisions and find solutions regarding a project which relates to their professional field, this approach supports the development of technical and transversal competencies and enables the linking of theory to practice” (Alves et al. 2013).
- **GILT research group from Instituto Superior de Engenharia do Porto** created a simulator called “Forces of Physics” to help learners understand the relation between the theoretical physics concepts and their practical application. “The simulator was intended to complement the more traditional educational process by providing the students with hands-on experiences”, therefore trying to implement an Experimental Learning methodology (Carvalho & Santos, 2013). This initiative points to a growing concern in establishing new Experimental Learning approaches in some curricular units.

In conclusion, it is possible to understand an emerging tendency of Portuguese higher education institutions in applying active learning methodologies. According to the examples found, these methodologies are being introduced mainly in medical sciences and engineering fields.

9. TYPICAL ACTIVITIES IN HIGHER EDUCATION FOR EXPOSING STUDENTS TO REAL-WORLD INDUSTRY PRACTICES AND ENTERPRENEURSHIP THROUGH ICT

The analysis of current practices for integrating industry process into higher education activities will focus both on formal practices at universities and informal / non-formal practices taking place beyond formal curricula driven by students themselves in their personal quest for new knowledge on subjects of their interest. Work was be conducted at each country represented in the consortium through partners, namely Greece, Spain, Estonia, the U.K. and Portugal to ensure a wide geographical footprint and a European dimension to the conclusion. It should be noted that, so far, only Agile related practices were documented since it wasn't possible to spot any Lean manufacturing related courses or actions in higher education institutions of the countries in which the partners are located.

9.1 In Greece

A research about teaching agile methods in Greek universities and Institutes was conducted in order to wrap up briefly the available courses that are held in Greek institutes and are correlated with agile methods, whether they devote a short time for teaching agile or a great number of lectures or even no teaching time at all. Finally, the research field of each one institute was depicted as research interests of the faculty or even as publications for conferences. For this purpose, a variety of universities, technical universities and technological educational institutes / universities of applied sciences in Greece was put in the spotlight for the needs of this report, in order to confirm whether they apply agile methods and to what extent.

Starting with the universities and their respective departments, through a thorough search in the official and active study guides, it was verified that:

- **The Aristotle University of Thessaloniki** engages third year students of the Department of Informatics in processes related with the analysis of the problems of today's software industry, with agile methods as well as with production stages and Software life cycle models in the field of the “Software engineering” course that is compulsory and lasts 52 hours on the whole. Furthermore, there is a lab called PLaSE[vi] (Programming Languages and Software Engineering Lab) that serves educational and research needs in many fields and specifically in the field of software engineering within which agile methods are involved among other processes.
- **The University of Economics and Business of Athens,** offers a full/part time postgraduate course in the field of informatics systems, named: “Audit informatics systems[vii], design and management of IT projects”. According to its study guide “upon completion of the course students will be able to know and use: international project management standards (PMBOK, ICB etc.), software development methodologies in general, with an emphasis on learning the UML language and adopting modern methodologies (RUP, ICONIX, Agile Methods, Extreme Programming, Timeboxing, etc.)”.
- The **Harokopion University (Athens)** and more specifically, its Department of Informatics and Telematics offers a course named “System analysis and software technology” which seems to be very close to teaching agile methods. The objective of the course is to help students understand theories, methods, and tools used to develop software and to gain some hands on experience in requirements engineering. Moreover, students are expected to learn how to use Unified Modelling Language (UML) and how to be familiarized with project management methods and tools. The contents of the course are described, among others, as relevant to Software Processes (Waterfall Model, Spiral Model, Rational Unified Process), Functional and Non-

Functional Requirements, Requirements Discovery (Interviews, Scenario, View-Points, Use Cases), Behavioural Models (Data-flow Models, State-Machine Models)" and so forth. The same Department offers the "Business Process Management or Business Process Automation" course, that targets business process management and business process automation and focuses mainly on the concepts of BPM and BPA, BP components, business process lifecycle, BPM and Workflows, automating BPs, alternative approaches and technologies and so forth. Moreover, there is the "Networked and Distributed Systems" course that intends to engage students in web-based information systems, principles of distributed systems and web services, synchronous and asynchronous models for distributed systems, management algorithms, synchronization and last but not least with state of the art trends like agile systems and design of information systems.

- **Τηε National and Kapodistrian University of Athens** and its Department of Informatics and Telecommunications (DIT) offer an undergraduate course named "Software Development for Informatics Systems" which, among other concepts, deals with Business Process Re-engineering that is directly related with agile methods.
- **The National Technical University of Athens** and its department of Electrical and Computer Engineering offer the compulsory "Software Technology" course that covers mainly RUP and XP methods.
- **The Technical University of Crete** covers basic principles for requirements analysis, design and implementation of large application software using methods and object-oriented modelling and development standards and development methodologies, such as waterfall models, model of rational and agile methodologies with its "Design and Development of Informatics Systems" course. As far as agile related research is concerned, there is significant activity reflected in

projects as AXIOM (Agile, eXtensible, fast I/O Module for the cyber-physical era) within the Horizon 2020 framework or in funding (€120.000 from 2010 to 2013) from the European Commission (DG INFSO) in the field of advanced adaptive automatic control methodologies.

- **The Technical University of Thessaly** offers two courses that partially engage undergraduate students in agile methods and techniques, agile project management and scaling agile methods. The first optional course takes place within the subject area of Applications and Foundations of Computer Science and is entitled “Education Technologies” while there is also the “Software Design and Development” course that introduces students to the importance and main concepts of software engineering, software life cycle, development process models, requirements elicitation and engineering. Among others, it negotiates modern software development process models (agile development, extreme programming, SCRUM) and two of the expected main learning outcomes are to help students understand the main stages of the software life cycle, the main software development process models (traditional and agile) and consequently apply them in real life projects. The students are asked to participate in a software development project in a collaborative manner in order to develop significant hands-on experience on the technical and administrative issues related to software systems development, as well as to the use of modern tools in this context. Finally, there is an officially documented number of lectures relevant to the agile methods, and approaches in the field of Applied Informatics for postgraduate students of the same department while in the research field.
- **The University of the Aegean** and more specifically the Department of Information & Communication Systems offers the “Software Technology” course in the 3rd year of undergraduate studies in order to

partially cover modern agile programming models and prototype development. There are either traditional real-time lectures or video recorded for off line use that analyse the agile approach and fully elaborate the agile methods such as extreme programming and SCRUM. “Methodologies and Tools Analysis and Design of Information Systems” is another course of the same department that deals with Methodology Rational Unified Process (RUP), CASE tools and Rapid Application Development (Rapid Application Development).

- **The University of Crete (Department of Computer Science).** Within the framework of the course entitled "Software Engineering", there is a number of lectures that analyse software production models such as Extreme programming model (agile development) or examine closely the issues of Agile software development, Software entropy, re-factoring (definition, common strategies, examples) and extreme programming.
- **The University of Macedonia (Department of Applied Informatics)** offers an MSc course in Applied Informatics, entitled “Advanced Software Engineering” and in its study guide, there is a specific mention about Agile Methodologies Software Development (Agile Methods).
- The **Panteion University of Social and Political Sciences**, within its postgraduate course in “Cultural Management” tends to engage its students in concepts and activities related with how to use Design Thinking to create and experiment with new ideas, Lean Start up methodology, Business Analysis and methodologies such as Waterfall, Agile, SCRUM, Kanban and so on.
- The **Technological Educational Institute of Central Greece** and its Department of Informatics offers the undergraduate course “Requirements Analysis, Quality Assurance and Software testing” which introduces students to agile software development processes.

- **The Technological Educational Institute of Crete** and more specifically the Department of Informatics Engineering enables undergraduate students to get to know the basics of agile programming, its methodologies and practices, methodologies adaptation, overview and comparison with other methodologies, implementation evaluation with agile programming philosophy in the context of the course entitled “Predesigned, Object Oriented and Agile Programming”.
- **The Technological Educational Institute of Epirus** is another example of higher education institute that foresees the necessity of agile and iterative methodologies especially for software engineers and for this reason it offers to undergraduate students the opportunity to familiarize themselves with flexible and iterative software development methods, SCRUM, XP (extreme programming, extreme programming), Unified Process (integrated process), software quality and testing, test-driven development in the framework of the course entitled “Software development”.

9.2 In Estonia

Experimental and active learning is a growing trend in all Estonian higher education institutions. However the lectures, seminars and practical workshops or labs are the teaching forms that prevail over practicing actual development models and processes. Higher education universities have some obligatory training practice at workplaces, and the ministry promotes new extended practice models at workplaces. Universities offer agile software development courses for IT students, additionally project management courses and trainings cover LEAN methods as one topic, and it is used as part of the startup team programs for students in some universities.
Higher Education institutions in Estonia provide some courses related with agile methods and LEAN such as the ones that follow.

Tallinn University offers an Agile Software Development Bachelor in Informatics. The course provides an overview of modern software development

methodologies, key software development trends, and tools used in process software development methodologies, their conceptual differences as well as the prerequisites of agile software development and incremental and iterative processes. It deals with other historical background of agile software development methodologies and different flavors of them while emphasis is also put on eXtreme Programming (XP), practices of agile methodologies, management issues and processes in agile team. Thus, learning outcomes are knowledge about agile software development (student knows and describes core principles of agile software development and is capable to differences between monumental and agile methodologies), understanding of agile practices and their objectives (student is capable to list agile practices, is capable to explain the essence, influence and relations between practices, also the reasons of defining those practices), capability of joining agile team (student knows key activities of software development, understands a nature on them and knows terminology used in software development process; knows what tools and for what purpose team uses, understands the need of using coding standards and uses it, is capable to use version control systems).

Tallinn Technical University:

- Software engineering 5 EAP - Unified Process and agile methods (OpenUP, Agile Unified Process, EssUP).
- Lean Design and Management - a short training course (8 hours) for construction students, goal is to give the overview about organizing design process more efficiently. The participant is informed about the general principles of lean design process; has heard about the practice of design companies in Nordic countries; is provided the information about design and management case studies from Estonian companies.
- IT project managers' development program, Agile project management - teachers agile methods, agile planning and Kaizen methods. The approach of teaching was panel discussion method.

- Project managers' seminar and Project managers' Day conference: "Lean Construction and BIM Yesterday, Today and Tomorrow", approach of teaching with experts from foreign countries and companies as presenters.
- Tallinn Technical University, Mectory: STARTERtech Advanced program for startups for student teams (Lean Canvas), 4 months program.
- Production managers' academy, training course, Module Optimizing production processes - LEAN as the dominating method (5S; JIT-Kanban; OEE ja SMED; JIDOKA).
- Department of Business Administration Chair of Operations Management offers Master and PhD study topics around LEAN methods (Lean thinking in enterprises, Lean production, Lean in Service, Lean & ERP, ERP implementation).

Tartu University:

- Course agile software development. The objective of this course is to introduce an agile method for software development that takes advantage of the principles of cloud computing and software as a service.
- Management of Software development, course, some topics related with SCROM (Challenges of Implementing SCRUM).
- Design Process management - one lecture in the course of agile methods.
- Agile processes and SCRUM-methodology have been in the focus of bachelor and master studies.

Several training providers provide training for LEAN such as TJO Consultation[viii], LeanWay[ix] and Addenda[x].

9.3 In Spain

The principles and values, on which agile methodologies are based, foster the acquisition of skills such as organizational capacity, teamwork, communication, or leadership, among others, defined in the EHEA framework as general or cross-curricular competences. However, there are no references to them or to active learning methods in the Spanish regulation because universities have full freedom to define both subjects and methods.

The Telecommunication Engineering White Book (ANECA, 2004) proposes the use of active learning on several occasions (e.g., pp. 405-407). It recommends different activities and proportions between the teaching hours and the student's individual work depending on the type of content. The ratio between practical and theoretical hours is also recommended for purely practical content. Specifically:

- Basic scientific content, namely mathematics, physics, programming: mathematics and physics need more teaching load, being the ratio of teaching hours to individual work between 1 to 2 and 1 to 2.5. In programming contents, students' individual work in a laboratory (practical) has to be prioritized with an approximate ratio of 1 to 4.
- Basic technological content, namely communications, computing and algorithms, hardware technologies: learning should be based on the resolution of problems and practical exercises, in addition to the study. The ratio of teaching hours to individual work would be between 1 to 3 and 1 to 4. In turn, they recommend that one-third of the ECTS should be dedicated to laboratory practices.
- Applications and solution methodologies on systems (information technologies and services, communication technologies and systems): here the book proposes to substitute the majority of master classes for the execution of individual or team works, its public presentation and the analysis of solutions found by each group of students.

- Personal skills and socioeconomic content, namely social and business areas: this content includes cross-curricula competences, including project management. Here, learning should be guided by the teacher, recommending a ratio of 1 to 2 between traditional teaching and student work.

In the Computer Science White Book (ANECA, 2005) the general recommendation about active learning is to adapt the contents and the teaching and evaluation methodologies towards the “learning to learn” approach (pp. 264). However, there are no specific recommendations. Furthermore, the proportions between teaching hours and student work are not set or recommended for any of the subjects or competencies described. Self-regulated learning is also considered an important generic cross-curricular competence.

The Industrial Engineering White Book (ANECA, 2006) devotes a complete section to cross-curricular competences divided into technical, systemic and personal and participatory. These include competencies such as information management, ability to organize and plan, autonomous work and learning or teamwork. One of the objectives of the Master's degree is to provide advanced training that will serve as a platform for updating knowledge and the practice of lifelong learning.

Regarding projects related with the experiential and active learning concepts Spanish universities are working on educational innovation to improve teaching and to adapt to the Bologna requirements. Proof of this is for example the “repository of good practices of educational innovation” developed by the Polytechnic University of Madrid (Universidad Politécnica de Madrid, UPM) and the number of projects developed (specifically in the UPM, 426 educational innovation projects in the area of industrial technologies and 296 in ICT between 2005 And 2015). In the specific case of engi-

neering higher education there have been many private initiatives of university departments that tried and try to include active and experiential learning in their classes. The following examples:

At the **Carlos III University in Madrid** (UC3M) it has been tested an active learning methodology to teach several subjects in Telecommunication Engineering, Telematics Engineering, Systems and Communications Engineering and Audiovisual Systems Engineering (Soto, Calderón & García, 2009). The methodology used is to provide students with information to prepare each class in advance, along with a schedule that details the work to be done at home. Face-to-face classes are used for reviewing the most complex ideas and the most important concepts, as well as for practical exercises. A forum of doubts is used as support for debating and tutorials. The evaluation system is continuous and takes into account students' active participation. The results obtained in the first experiment were very positive and the methodology has continuity since then.

Another project is the one carried out at the **University of Alicante** (specifically, in the Escuela Politécnica Superior, Universidad de Alicante) for the subject of Networks (Baeza et al., 2011). This project, based on blended learning, combined the theoretical classes with online practices that formulated interactive exercises and proposed the use of virtual laboratories to test the knowledge acquired in configurations different from those of real laboratories. In addition, this system had a self-assessment test so that the students could check their level.

Another good example of active learning is the approach followed to teach "Computer Peripherals and Human Interface Devices" for the Degree in Computer Science from the **University of Granada** (Rojas, 2013). The methodology used was based on active and cooperative learning. The students had to experiment with case studies on common projects collaborating with peers and using real applications. The findings in this experience

tell that the students' learning process improved experimenting with tangible real-world projects.

At the **University of La Laguna** (Escuela Técnica Superior de Ingeniería Informática, Universidad de La Laguna) active has been in constant use since 2004. Specifically, in the subject "Human-computer interaction" the methodology was based on projects and collaborative work following a blended learning format through Moodle. In later years, multiplayer video games have been integrated with Moodle (González & Blanco, 2008) introducing the creation of collaborative concept maps and the use of collaborative working environments to support the development of the User-Centered Design (UCD) methodology. More recently the focus has been put on cross-curricular and professional competences as well as on the use of e-portfolios and social networks such as Twitter and LinkedIn (González, 2015). Over the last few years PBL methodologies have been applied using project management tools as well as other 2.0 tools for creating collaborative learning environments, and have used Design Thinking (DT), Visual Design (VD) and Gamestorming (GS), especially during the prototyping phase. In addition, specific training on agile methodologies (SCRUM and XP) has been included as part of the content of the subject. During the development of the projects hybrid methodologies mixing SCRUM or XP with UCD, DT, VT and GS, have been deployed successfully.

An example of the application of agile methodologies to encourage active learning is presented in Pérez et al. (2012), carried out at the **Polytechnic University of Madrid** (UPM). In this project, called *Agile Learning*, they have adapted the SCRUM methodology to the academic framework to implement teamwork, frequent deliveries in incremental iterations and retrospective SCRUM-like meetings. This project aims at enabling the student to use agile development methodology in a natural way through experience. Thus, they have defined the concepts of Working Product, which is each of the works/deliveries to be made during the course, and Final Product, which is the set of working products evaluated during the course. The process is

carried out in several phases: the definition of the SCRUM team, which depends on the total number of students and the amount of work to be done; the definition of sprint, whose duration must be constant (the recommendation being between 2 and 4 weeks), the selection of the agile practices to adopt and the adoption and adaptation of the selected practices to the context of the team as the availability of working hours has to be considered. One of the keys to the success of this project is the realization of retrospective meetings that address the problems encountered in each sprint and where the teams consider possible solutions and improvements to be tested in the future. These retrospective meetings were held during tutorial hours between the team and the teacher.

It should be noted that there are no institutional proposals in Spain to foster the use of serious games or other technology trends. The government regulations do not contemplate the use of technology in any way, and the White Books just focus on the development of competencies to adapt to new technologies, but do not specify their use to teach or support learning. However, there are several relevant initiatives aimed at fostering and enabling the use of new technologies and serious games. A good example of this is SEGAN (Serious Games Network), a community of practice to exchange ideas and experiences related to serious games formed by several European universities, being the Universidad Complutense de Madrid and U. de Zaragoza among them. At the same time, several proposals of small research groups in several Spanish universities focused on using upcoming technologies for teaching engineering. What follows is a list of the most relevant initiatives related to the inclusion of serious games and other technology trends to teach practical subjects:

- Studies of use and methodologies to include serious games in higher education. The **Department of Computer Engineering and Systems at the University of La Laguna** has made a methodological proposal based on the introduction of gamification techniques or

game mechanics in the process of teaching Computer Science (González & Mora, 2015). For this, they have analyzed the video game mechanics that are been used the most in education and how to introduce them into educational activities in a blended learning scenario. Their methodology, called GAMIFULL, is aimed at strengthening the engineering students' motivation through games and ICT. Their method is divided in five steps: analysis of users and context, definition of learning goals, experience design, resource identification and application of gamification elements. They tried this methodology in the subject "interactive interface design" using practical work and project based learning. The students had to design and prototype a mobile application accomplishing eight tasks divided in four phases. The students got points from each deliverable or activity in the subjects' social networks. The points obtained were displayed on scoreboards and rewards were used motivate the students. In this case study they used several technologies: Moodle, social networks (Twitter, LinkedIn, Google+), Siena social for the evaluation, Google Drive for digital portfolios, Trello for project management, Scrapfy for collaborative coding and their own application for register the work done in virtual and real laboratories. They also proposed the use of a gamification platform like Badgeville, Bigdoor, gamify.ws, etc. to apply game mechanics and monitor the students' progress.

- **e-Adventure**, a serious game design tool: The eAdventure platform is a research project developed by the e-UCM Research Group at the Faculty of Informatics of the Complutense University of Madrid (Torrente et al., 2010). It provides an environment to create educational games and simulations based on point-and-click adventure games. The project is open source and it was written in Java. It does not require programming skills.

In addition, there have been just a few initiatives to teach agile or lean methodologies using technology or serious games in recent years, such as:

- **Agile Moodle**: In the Polytechnic University of Madrid and within the Agile Learning project mentioned in the previous section (Pérez et al., 2012), a Moodle modification, called Agile Moodle was used for the use of SCRUM in their classes. Agile Moodle supports the definition of iterations, i.e.sprints, teams and the realization of retrospectives, and allows collaborative work. The content is structured in iterations, as well as the tasks and works to be developed. The set of deliverables that is the result of each iteration forms a Working Product. After the face-to-face retrospective meeting, the retrospective activity is enabled in the system to carry out the co-evaluation of the cross-curricula competences of each team member. The skills evaluated are analytical skills, organizational skills, teamwork, critical thinking and leadership.
- **Trello and Google Drive for project development**: At the University of La Laguna (Escuela Técnica Superior de Ingeniería Informática, Universidad de La Laguna), as we have seen in the previous section, they have used several technologies and methodologies to teach project development (González, 2015). Specifically, they have carried out practical training in project development using agile methodologies (SCRUM/XP) and Trello as a project management tool, using as well Google Drive for collaborative work and Twitter for content exchange, analysis and selection of relevant information from for the subject and for participation in expert groups and national and international professional communities. The delivery of reports, evaluations and final evidence was done through Moodle.
- **Kanban board activity**: At the University of Valencia, the department of Computer Systems designed a teaching activity that recreates a production line using a Kanban board to visualize the state of the process. This activity was created to teach the use and interpretation of a Kanban board and other associated elements, such as the concept of Work in Process (WIP) and the use of Cumulative Flow

Diagrams, doing all of this only in one class session. The passage of time is simulated with snapshots where the state of the process is recorded. After each round the workflow metrics are calculated and the Cumulative Flow Chart is updated. Based on this information, teams discuss some changes that could improve workflow indicators in a next round. The technology used to develop the activity is Trello, where a Kanban board is defined for each team. The board has five columns, one for each part of the sequential process, including one for pending orders at the beginning and a last one for completed orders. Trello cards that can be moved between columns, from left to right, represent the working units representing the workflow. They also created Cumulative Flow Diagrams in Excel to observe the WIP evolution. They also use flow metrics like Production Rate or Cycle Time based on the snapshots (in this experiment, a snapshot was taken every 30 seconds). The work was represented by drawing on a paper the production process to avoid the costs of other strategies like using building blocks like Lego (Krivitsky, 2011).

9.4 In the U.K.

While in the U.K it is still relatively early days regarding the implementation and integration of agile and lean courses in higher education, however, the potential and opportunity for the deployment of such methodologies is large and this is reflected in the continuously expanding list of Masters degrees that are related to agile and lean. Even if not extensive, the following list of graduate courses is indicative of the interest:

- **Coventry University** offers a full/part-time MSc course in “Engineering Business Management”. This course introduces students to all the key aspects of managing a company in the engineering sector and helps them develop an integrated understanding of strategic

and operational management and acquire the appropriate intellectual and personal skills required to successfully operate in a demanding management environment.

- **University of Leicester** offers a 1 year MSc/PG Dip in “Agile Software Engineering Techniques”. According to its handbook, this course aims to provide a sound background on the methods and techniques that can meet the modern challenges regarding increased levels of flexibility and agility.
- **University of Wales, Trinity St David** offers a Masters course in “Lean and Agile Manufacturing”. The program reflects the current industrial demand for expertise in lean and agile manufacturing techniques and it involves activities that play a key role in managing the extended enterprise. In addition it involves activities that focus on designing products and processes for manufacturing, while managing risk at the design stage of product development and process planning. The discipline embraces areas such as supply chain management and logistics, which are key to competing in global markets and providing world class service.
- **Heriot Watt University** offers a 1 year “Lean Six Sigma for Operational Excellence” graduate course. The course aims to develop high-calibre graduates with an in-depth understanding of strategic, tactical and operational issues as well as of the tools and techniques of Lean Six Sigma methodologies. Students are expected to learn state-of-the-art concepts, methods, principles, tools and techniques, relating to quality and process improvement for a broad range of organisations, such as manufacturing, service, public sector and third sector, set within a global context.
- Another MSc course offered by **Heriot Watt University** is the 1 year “Logistics and Supply Chain Management with Lean Six Sigma”. The course is designed to provide in-depth understanding of current practices, trends and issues in logistics and supply chain along with

the tools and techniques of Lean Six Sigma methodologies. It also looks at broad strategic issues of organization management and how these impact on continuous improvement. Students have the opportunity to take part in team-building and leadership events during the first few weeks of the program.

- **University of Strathclyde** offers a 1 year “Lean Six Sigma for Process Excellence” MSc course. The course gives participants an in-depth understanding of process excellence issues related to all industry sectors, both manufacturing and service. It also provides education to a level of world-class practice in quality management to enable students and participating companies to gain competitive advantage through the application of basic and advanced set of tools and techniques of Lean Six Sigma methodologies and to demonstrate tangible and quantifiable results to the bottom-line. Participants are equipped with state-of-the-art concepts, methods, principles, tools and techniques relating to quality and process improvement for all sorts of organizations in a global context.
- **University of Central Lancashire** offers a 3 years part time MSc course in “Agile Software Projects”.

9.5 In Portugal

Portugal has not yet entered fully the trend of applying emerging technologies as learning tools in higher education. A study from Universidade do Algarve associates the degree of use and diffusion of games and learning simulations in education with three aspects: jobs in knowledge intensive activities, levels of educational qualifications and electronic governance (e-gov). The results show that even having registered an increase last year, Portugal has the lowest levels within the European Union’s average regarding the three aspects. According to the study, the low levels on those three

aspects may be one of many explanatory reasons to Portugal's low expression of game based learning in education, when compared to other countries (Kikot et al., 2015).

Regarding Videogames, the trend is similar. Portuguese are one of the European people that play less videogames. Nevertheless, this scenario is changing. A study from Universidade Aberta shows that in a sample of 689 students from Universidade de Coimbra, 63.3% said to be a videogame player. And in a sample of 161 students from Universidade dos Açores and Universidade Aberta, with ages between 18-63, 85.1% have played at least once a videogame. And even though there is a difference registered between younger people (higher chance of having already played) and older people inquired, the difference is minimal (Lopes & Oliveira 2013). However, this doesn't necessary mean that the videogames were played in class, or had any educational purpose. Hence, despite being very motivational and allowing the 4development of many competences, videogames as an educational tool is still little used in Portugal.

In what concerns serious games in higher education in Portugal and according to a study done by Universidade Aberta (Lopes & Oliveira 2013), it is accurate to say that the use of serious games is rare. The teachers and the fact that the majority of serious games available are not translated to Portuguese are the main factors pointed out to explain the lack of use of serious games. However, the same study emphasizes that most youngsters believe the use of such tool in classes would have pedagogical benefits and that the growth of this serious games market is also expected.

Despite this general scenario, a few of the existing serious games are already used in Portuguese higher education or have at least the possibility to be used. However, the majority of them mainly serve as a tool to support some curricular units, and most of the times they are not formally integrated in the degree curricular program.

During the academic year of 2010/2011, the Integrated Master Degree on Industrial Engineering and Management at Universidade do Minho has formally included a serious game designated “Cells Design and Operation Game”. The game was integrated in the curricular unit “Design of Product-oriented Production Systems” and addresses the assembling of a product. This serious game was applied to strengthen the learning of new concepts: the different operating modes that can be implemented in a production cell (Moreira, Alves, & Sousa, 2013).

The eCITY serious game, that stimulates the integration and continuous exploitation of Problem Based Learning in engineering schools, is a serious game that can be used as a support tool, but has the potential to be implemented in higher education programs (eCity, S.d.).

The Gaball project that has a methodology based on a serious game approach is also an example of a serious game that can be used as support tool or even formally implemented in curricular units. Gaball seeks to address the reinforcement of EU Micro and SME’s managers’ skills in the process of internationalization to internal and external markets through electronic business platforms. The project is also addressed to final year higher education students that can potentially become entrepreneurs and are planning to start up their own companies (Gaball, S.d.).

Universidade do Algarve makes use of a simulator in the Bachelor Degree in Enterprise Management. In the last semester of the degree, students can choose the curricular unit “Entrepreneurial Games” which explores a business simulator - Cesim Global Challenge - for learning purposes. It integrates the various areas of management and facilitates the development of diagnostic, analysis and decision making skills in the context of overall management. The course unit had 29 students enrolled in academic year 2012/2013 working with the business simulator (Universidade do Algarve, S.d.).

Physical simulation games are also becoming more mainstream especially in engineering higher education. At the Integrated Master Degree in Industrial Engineering and Management at Universidade do Minho, physical prototypes were integrated as a new approach to teaching. These prototypes involved the design of a production system using Lego® Mindstorms® NXT building blocks (Moreira, Alves & Sousa, 2012).

At **Instituto Superior de Engenharia do Porto** a study addressed especially lean physical simulation games. “It compared two different game approaches to lean training: a simulation game based on a single realistic manufacturing platform, involving production and assembly operations and a digital serious game that replicates a production environment that demonstrate the potential of lean tools. The results showed that both approaches promote trainee motivation and knowledge acquisition and suggest that they can be used in a complementary way to achieve more effective learning results” (Carvalho, Lopes & Ramos, 2014). The results were obtained from simulations executed by 48 students of the Master Degree in Mechanical Engineering from Instituto Superior de Engenharia do Porto during the academic year 2011/2012. They show a growing tendency on the need to implement different technologies in learning processes.

Regarding e-learning, Portugal shows a different trend. The study “Governação & Práticas de e-Learning em Portugal“ indicates an upward tendency in distance training practices (e-Learning and b-Learning). However, there is still not a systematic offer rooted and institutionally normalized. In higher education institutions there is evidence of good practice in progress, but except for the case of Universidade Aberta, higher education institutions that offer e-Learning courses that give certification is residual (Dias et al., 2014).

The majority of higher education institutions offers platforms such as Moodle, Formare, Blackboard and other web teaching tools to support class-

room learning, and in some cases less frequent, to develop education offers/online courses for distance students (Dias et al., 2014). But in high education institutions there is still “a predominance of the use of non-classroom learning management platforms and, even in the online environment, the traditional classroom is still very present” (Marques, 2015).

Nevertheless, according to the report on e-learning (Dias et al., 2014), Portugal has already some good practices examples:

- **Instituto Politécnico de Leiria**: 8.9% of bachelors and 8.3% of master's degrees in b-Learning - with tutor in all curricular units. Three training e-learning courses with tutor. All curricular units are based on a collaborative model, by doing tasks on a platform or by using web2.0 tools.
- **Universidade Aberta**: provides complete e-learning bachelor, master and doctorate degrees.

Furthermore, a thesis study from Faculdade de Engenharia da Universidade do Porto (Marques, 2015) addresses more aspects regarding e-learning:

- The **Instituto Politécnico de Castelo Branco**, introduced an e-learning platform “Teleformar” at Escola Superior Agrária de Castelo Branco. This platform has now established itself as a support tool for all curricular units of the Instituto Politécnico de Castelo Branco, at all educational levels and types of courses.
- At **Universidade de Aveiro**, 81% the students said they use technologies that enable interpersonal communication and 70,1% said they use learning management platforms. Virtual environments are taken as the Communication technologies less used.
- At **Instituto Superior de Engenharia do Porto** an analysis proved that the use of Moodle as an e-learning platform is minor, being that

only two departments – Computer Science and Electrical Engineering – use it more intensively as such. The rest of the departments use Moodle more as a repository.

As conclusion and “in order to respond to the specific purpose of analyzing the current situation of higher education in Portugal at the level of use of ICT with pedagogical purpose several studies were collected in various higher education institutions in the public and private sector, university and polytechnic. In all analyzed cases it was found that were shown improvements in the teaching-learning process through the use of web and learning platforms verifying that a large number of high education intuitions nationwide have used learning platforms and other technological resources in their curricular units“ (Marques, 2015).

10. THE LEAP CASE STUDY ON THE DEVELOPMENT OF LEAN PRODUCTION AND AGILE MANUFACTURING LEARNING REQUIREMENTS

This section aims to shed led into the LEAP questionnaire based study that aims to inform the design and implementation activities of the project by introducing feedback from stakeholders. The case study complements the review presented earlier in this report, which analyses the current situation in countries in which the consortium has project partners in relation to building skills on agile and lean practices in higher education.

The case study aims to inform the LEAP serious game, namely an application that is designed for non-leisure purposes, and specifically designed for learning. The game will prepare higher education students, with an emphasis on engineering principles, for better transitioning into the world of work through their exposure within higher education learning activities to emerging industrial processes, such as agile and lean production design.

The LEAP serious game educational objectives will be:

- To expose higher education students to agile and lean industrial practices.
- To prepare students so that they can effectively transfer experience built through the LEAP serious game into the real-world in related educational and future professional activities.
- To build entrepreneurial mind sets, critical thinking, and collaborative capacity all of which are part of the proposed agile learning solutions.
- To encourage learners to think and act as professionals through role-playing that challenges them to introduce solutions to everyday life problems.
- To raise awareness on the need to align higher education activities to industry requirements.

The LEAP learning goals help address the New Skills for New Jobs initiative objectives and specifically the need to close the gap between available skills sets to those in demand by industry promoting sustainable economic growth through the development of human capital, promoting employability, and social cohesion. They further address the PISA and ET2020 objectives in relation to building transversal competencies that help learners excel in academics and at work independently of subject area (PISA 2012).

The high level objectives of the serious game will be:

- To build the capacity of higher education students to understand agile product design that is highly user-centred.
- To build the capacity of students to understand lean product design which promotes the responsible use of resources thus being friendly to the environment and more.
- To build the capacity of students to apply agile and lean product design in the context of projects.
- To empower students to think out-of-the-box in an entrepreneurial manner for introducing viable solutions that are environmentally friendly and respectful of users / consumers.
- To encourage learners to adopt user-centred approaches in the design of solutions that address real world needs of consumers.
- To promote the transferability of the above skills from educational contexts to real world situations.
- To link the game learning objectives to higher education curricula with a focus on engineering principles in countries in which the LEAP consortium has partners (see O2).

Game design will take into account the results of O2 on learning requirements definitions. Specifically, it will take into account the following aspects

in all 5 countries in which the consortium has partners (Greece, Spain, Estonia, Portugal, and the UK):

- The current situation in higher education in relation to integrating industrial processes into formal and informal activities.
- The objectives of higher education curricula, with a focus on engineering principles.
- Technical infrastructure available in higher education institutions in different countries for deploying ICT-enhanced learning solutions.
- The interests of educators and students.
- The skills demanded by industry players for employing higher education students after the completion of their studies.

The game / software application design activities will include:

- Identifying of appropriate "gamification" mechanisms that will be integrated into the serious game. "Gamification" refers to the integration of gaming mechanisms into learning contexts with the objective of promoting learner long-term engagement in learning activities and fostering retention of knowledge. They may include rewards in the form of elements to be gained upon completing successfully tasks (badges, stars, etc), leader boards that show the relative success of one user as compared to that of others, opening of additional educational levels upon achieving a specific level of success, helping others to be successful, social recognition by peers, and more.
- Designing feedback mechanisms that allow scaffolding of knowledge by allowing learners to know in real-time the results of their efforts.
- Designing the interactivity of the software application, i.e. how users with interact with the game; this may include dialogue boxes, feedback boxes, notes on completed tasks, and more.

- Designing industry-inspired learning scenarios that will be linked to learning objectives

In terms of learning scenarios, learners will be challenged through role-playing to synthesize solutions to exercises that are inspired by real-world issues and can be solved by deploying knowledge in engineering principles. The learners will further be challenged to applying agile and lean processes ensuring that their solution integrates user needs and conserves resources. The LEAP project consortium taking into account everyday life issues of interest that can be solved through engineering as well as educational curricula in each country that LEAP has partners will collectively design the scenarios.

The serious game will be multi-platform and will be executable on popular operating systems and devices. This flexibility will allow the deployment of the game not only in formal classroom practices by also in wider blended learning contexts that may combine classroom instruction, visits to industry, and other external activities.

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10.1 LEAP activities engaging external groups representative of target users during the design stage

During the design stage of the game, the LEAP team carried out several activities that aimed at generating and gathering useful feedback from stakeholders and specifically students with a profile similar to that of potential users of the LEAP serious game after its completion and release. Such activities were carried out almost from the beginning of the project in order for the design and implementation team to gather useful feedback about the interests and needs of potential users thus strengthen either the quality of

LEAP methodologies or the proof-of-concept serious game and its supporting teaching material and resources. This section aims at putting a spotlight on the ideas and suggestions of students and future users of the serious game that the team took into serious consideration even before implementing the design of the LEAP game during the pre-design engagement activities.

The main activity was carried out in Greece, at the University of Thessaly and more specifically during the course "Educational Technologies" (Course ID HY310) that is integrated in the curriculum of the Department of Electrical and Computer Engineering. It is an elective undergraduate course, relevant to the subject area of Applications and Foundations of Computer Science, and offered during the 5th semester, namely the 3rd year of the studies. It consists of 4 hours of lecturer's attendance per week and three assignments, all of which have direct connection with the agile methods, the agile development techniques, the agile project management and the scaling of agile methods.

The students were asked to participate in a software development project in large groups and they had the opportunity to attain hands-on experience on the technical and administrative issues that are generally related to software systems development, as well as to use modern tools used within this context. It was rather important that these students and future software developers were engaged in the procedure of designing an application from the ground up while respecting the needs of potential customers and this is reflected in the scenarios that they all built up and contributed after a series of lectures and advisory discussions with the lecturer. Most of the suggestions and scenarios were concentrated around the idea of designing and implementing a game, software or a mobile application but among such projects there have also been ideas for hardware or other products:

- **Project idea1: Smart House.** The scenario is about an employer that asks for the conversion of his house into a "smart home". In the

context of gameplay, a team of electricians will have to deliver this project, overcome any difficulties and take into consideration the customer's needs and feedback. The players would have to design and install the necessary software and hardware and keep in mind that adding extra capabilities over time are essential for addressing emerging needs.

- **Project idea 2: Battery is running out**. This project takes off the basic idea that, nowadays, having a charged battery for all the mobile devices used by a single individual is very important. Furthermore, power-banks often either don't prove very reliable in a very busy day. Other times a person may forget to charge the batteries, a tedious task at best. Thus, a good idea would be to sell really cheap batteries not only in consumer electronics stores but also in supermarkets and kiosks. The team that invented this scenario, proposed the concept of a really cheap and effective battery that would be strictly one-use, made of recyclable materials, it would come with a universal adaptor and could easily provide energy and autonomy for at least two hours time. In the proposed scenario, the team suggested that the device should cost preferably up to 1 Euro and that its selling points should be carefully chosen in order to keep the sales high. The design and manufacturing team should have the chance to redesign and improve the product according to clients' needs and feedback that could be generated on the fly while using the device.
- **Project idea 3: Web based app for online orders.** The proposed scenario refers to the implementation of an application that would allow comfortable and effective management of product orders regarding computer parts used by company employees or by customers. The team would have to actually design and implement a "clever" product market manager for professionals. Future plans would include the development and optimization of the application to be used by customers through their personal computer or mobile device. The

application should check online and real-time the availability of each product highlighting their characteristics and general information, which would be stored in a database. In addition, it should manage the process and the way of trade, the history and the status of each customer's orders as well as possible comments and extensive or brief assessment of products.

- **Project idea 4: e-Museum app.** This scenario is about the development of an application that acts as an art exhibition virtual space of a museum. The app should be able to provide information on the role of the museum and to gradually expand to streaming a real-time presentation while offering relevant information regarding the museum operation. One of the always evolving and changing features of the app would be related to exhibitions and events that would appear according to public interest, demand and requirements or based on new trends and needs that call for further changes and optimization.
- **Project idea 5: Instaorder.** This scenario is about a suite of applications for all platforms (iOS, Android, WP, web) to be used in stores such as cafes and restaurants that would change the way customers order and pay. Work involves designing the service, delivering a fully working product and ensuring the functionality of the server that supports the entire platform. The suggested application would have several services. A service for the store customers would be divided into two distinct parts: the front end on the user interaction with the application and the back end regarding the interaction of the application with a device such as the GPS network support, etc. The store service would include a front end to be deployed by mobile waiters and a computer store and the back end that, except for the communication of the store computer to the host server platform, would include all the software managing orders and all the required accounting processes. Last but not least, the design of the server software would

support the whole platform in order for it to function properly and efficiently at all levels. The end customer would use the application to connect to the platform, choose among the available stores and pick the right service such as: order / payment, check availability of tables/space, provide feedback, store rating.

- **Project idea 6: e-Student app.** This idea is about an application originally designed to display specific field notifications so that every student could ensure ubiquitous and uninterrupted access to school's announcements coming from his or her department's secretariat. Initially, a basic condition would be to link the application with the secretariat's website via RSS in order to push and display notifications to the application. Students' feedback would be more than welcome in order to ensure the application's functionality. Moreover, through feedback the students could express their preference about news features that could change over time according to their emerging needs.
- **Project idea 7: Virus detective.** This is an idea about a single player strategy game where the player would be asked to stop the infection from a dangerous virus and generate appropriate treatment and ways of addressing any possible collateral effects. Initially, the user would take the role of a scientist that would have to deal with viruses of various degrees of resistance and expansion rate. At the beginning gameplay the player would be given a sum of money that could be invested in research and help gather information. The categories of research directly related to the characteristics of the organism would include possible symptoms, transmission methods, transferability, addressing the geographical characteristics of the spread, resistance degree, mortality and more. The microorganism could exhibit new features and combination of existing ones so the scientist should either inform citizens about how to defend themselves and stay safe or to address the spread by proposing appropriate measures.

- **Project idea 8: Accessible education.** The central idea of this scenario is the creation of an online problem-reporting platform addressing the needs of a student community and more specifically the issue of handicapped individuals that are in need of easy access to academic education, uninhibited mobility to, from and within the university and appropriate and functional structures for their needs. The university's departments would be asked to promote the platform in order for students to become familiar with it. Handicapped individuals or others that help them would have the opportunity to gain access to the platform and report either problems or improvements that are related to mobility issues or other problems that make access to education difficult. The people involved in the platform would continuously evaluate and take into consideration all this feedback from users.
- **Project idea 9: Idea's simulation.** According to this scenario, the objective was about the development of an application with which the user could plan, virtually test and eventually establish his or her business. Specifically, in a graphic environment the users would be able to experiment and simulate the development of a business and define its success according to their options but in fact without any real failure risk. Initially the user selects a company that already exists and runs successfully.
- **Project idea 10: Urban Mobility plan.** The core rationale behind this scenario is that cars overwhelm modern cities. Pedestrians have limited and narrow sidewalks and cyclists on cycle paths. The Urban Mobility app could promise a greener, cleaner and friendlier city for urban living through specific features such as letting the user know about the crowded parts of the city, for example museums, sports venues, transport stations, etc. or through the use of ubiquitous sensors that could collect various data, such as pollution rate, vehicular traffic, temperature and so forth. Changes to be made by users within

gameplay towards solving a specific problem would not be static but rather dynamic in a way that these changes might affect the existing situation of the game by creating other issues in various sectors of urban life, such as congestion or traffic jam.

- **Project idea 11: Sketch your home.** This project appeals to architecture students and allows them to design a house through a step by step process and share their design ideas for the home of their dreams with other peers. Initially, the user could design the external part by providing a front and a plan view of the house. If the final image of the first phase became accepted, the user could proceed to the next phase, otherwise he or she would be called to improve the design. In the next phase, the user would be engaged in the construction of the interior while the final stage would involve the decoration and the installation of various devices. At the end of each stage, the user would share his or her plans with the other players of the game that would get the chance to assess the final product and contribute with useful comments and suggestions for improvement.
- **Project idea 12: Agile Automotive design.** The aim of the following scenario is the creation of a serious play with agile design aimed at higher education students of polytechnic schools. More specifically, it would address mainly electrical engineers, computer engineers and mechanical engineers. In this game, the student would have the opportunity to create his or her own car based on a range of options and functions which could be changed and upgraded anytime in order to satisfy the customer's requirements and needs. As soon as the game begun the manufacturer-student would receive the order of a vehicle by another user classmate-buyer. Initially, the manufacturer-student could choose the technical and aesthetic specifications of the vehicle that would then be delivered to the buyer-student, who could either accept it or identify and report any required changes. This scenario would aim to introduce the manufacturer-student to the

process of agile design, thus contributing to the development of critical and entrepreneurial thinking and creativity.

- **Project idea 13: Market for students:** This is a scenario addressed to all students enrolled in Greek universities regardless of department or subject area. The scenario is relevant to creating an application designed specifically for mobile phones / smart phones using Android software. The app would aim to provide students with exclusive updates for student services and product offers and to provide all information necessary to facilitate the acquisition of these offers.
- **Project idea 14: Erasmus Greece.** This scenario addresses Erasmus students and generally all students of Greek universities with the main intention providing an informational service to students who decide to study abroad for a period of time. It would be available at all times in order to provide suggestions and information and to familiarize someone with their new environment. Erasmus Greece would utilize tools like Google maps and GPS. Based on the area where the student would be found and based on student interests the application could guide the student through suitable suggestions. The application might have the following areas of interest: provision of information relating exclusively to the Erasmus program and constitute the FAQ area for students; for example, this might include information on tuition fees. Other information might include the necessary documents (Learning Agreement, passport photos, EHIC) that a student would need during his or her studies abroad. Information on flights, ferry tickets, entertainment, events, restaurants, cafeterias, various places of cultural interest might also be provided. In fact, in order for this application to function well and to serve efficiently as many users as possible, it should not remain stagnant but rather evolve through the dynamic integration of emerging information.

- **Project idea 15: Video club data base.** Application for students of Polytechnics, Department of Electrical and Computer Engineering. Students would be asked from the application to develop a database for a shop that rents and sells movies and games. Initially, the application would ask the student to implement a database of customer information based on a diagram and then to implement it with SQL code. The implementation of the database would be gradual. At each implementation stage, the application would have specific requirements for the operation of the database, such as the fact that the customer would not have the possibility to rent a product if he or she had not already returned a previous rented item and so forth.
- **Project idea 19: Computer Architecture simulation.** This scenario is aimed at students of the Department of Electrical and Computer Engineering (ECE) and students of Computer Engineering department who have selected the materials sector (hardware). The scenario revolves around the creation and simulation of circuits using basic circuit elements for producing electronic architectures. Main activities of this scenario could be an analysis of the circuit elements that contribute to the development, investigation and proper circuit operation with chips, microchips, transistors, and other devices, integration of those and analysis of the final functionality. Through gamified scenarios students would become familiar and pleasantly build knowledge on the operation and use of circuit elements that are essential for the development of relevant technologies in the industrial architecture industry. Within this scenario, circuit element planning would be essential. Essential would also be the assessing of their proper functioning according to local requirements in order to implement products that address local economic sectors and companies.

10.2 Questionnaire for the LEAP survey on agile skills development

Complementary to the aforementioned engagement-dissemination activities and to the review of policies, strategies, initiatives, and projects presented above, is the case study that the LEAP team performed among higher education students in relation to establishing the current situation regarding the topic of the project, their learning needs, their knowledge on lean and agile practices and the educational use of serious games. It provides field input from the individuals that are potential users of the serious game that the LEAP team develops. The study was performed in Greece, Estonia, U.K., Spain and Portugal. A questionnaire was developed and was made available strictly online through the Surveymonkey® platform. The questionnaire is presented in the Appendix of this report and the results of the case study are presented below and they are based on “structured” questionnaires that involve mainly multiple choice, closed questions and deliberately limited open questions.

The data presented in this summary does not in any case aim to support quantitative analysis but it rather boosts qualitative assessment and its clear objective is to help gather useful feedback from students and potential users of the serious game in the countries that participate in the project. The process of generating the aforementioned data was open until the end of June 2017 and the total number of participants that took part in this small-scale survey were 246 students and more specifically 134 from Greece, 21 from UK, 26 from Estonia, 33 from Spain and 32 from Portugal. Most of them, a total of 84.6% are aged between 18-30 years old and they are currently studying at University. The majority (36.2%) states that at their University, the courses related to software/product development processes and methodologies are more than five, while 69 of them (28%) declare the existence of at least 1-2 such courses.

Q1 What is your age?
Multiple Choice

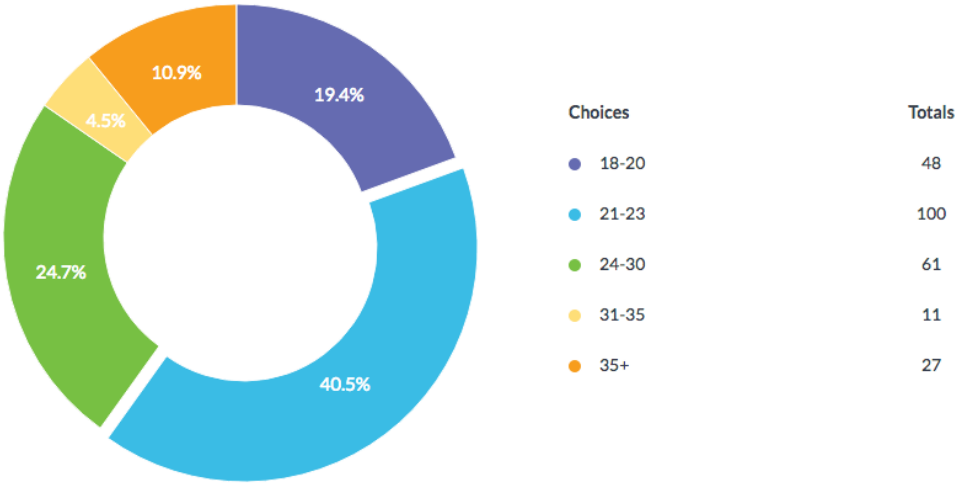

Figure 3. Participants' ages.

Q2 What is your academic background?
Multiple Choice

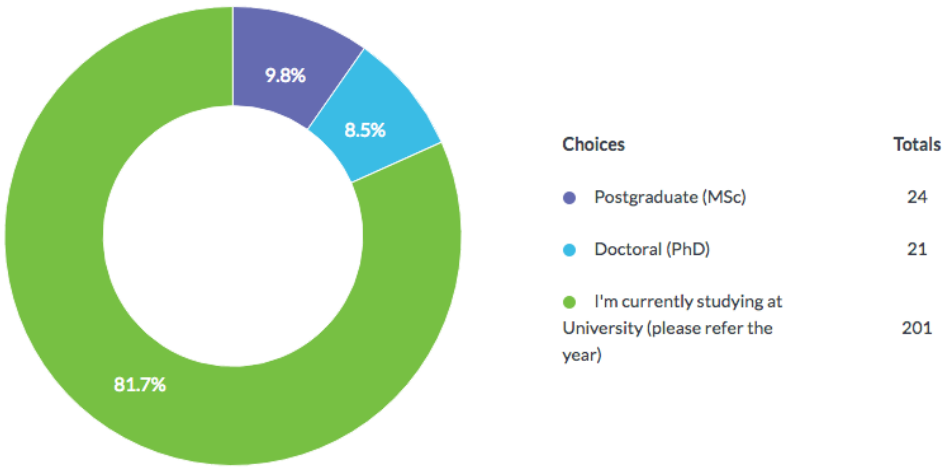

Figure 4. Participants' academic background.

A surprising fact is that 37 of the participants (15%) are totally unaware of the existence of relative courses, which means that they have never been practically exposed to product development and methodologies processes during their studies so far.

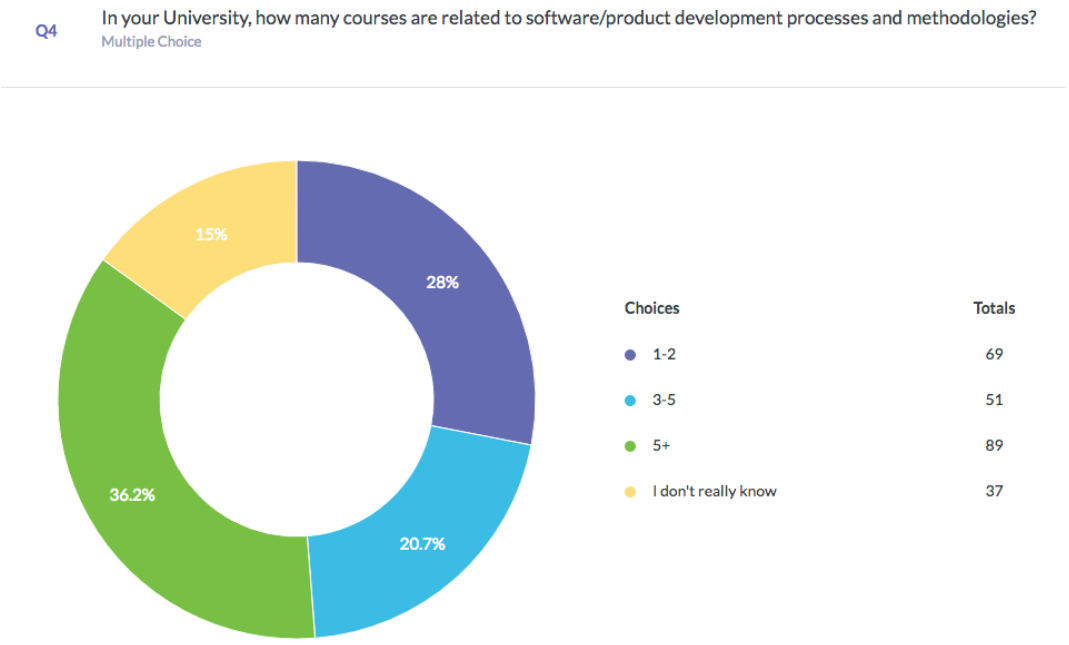

Figure 5. Participants' responses on the offering of agile courses at their universities.

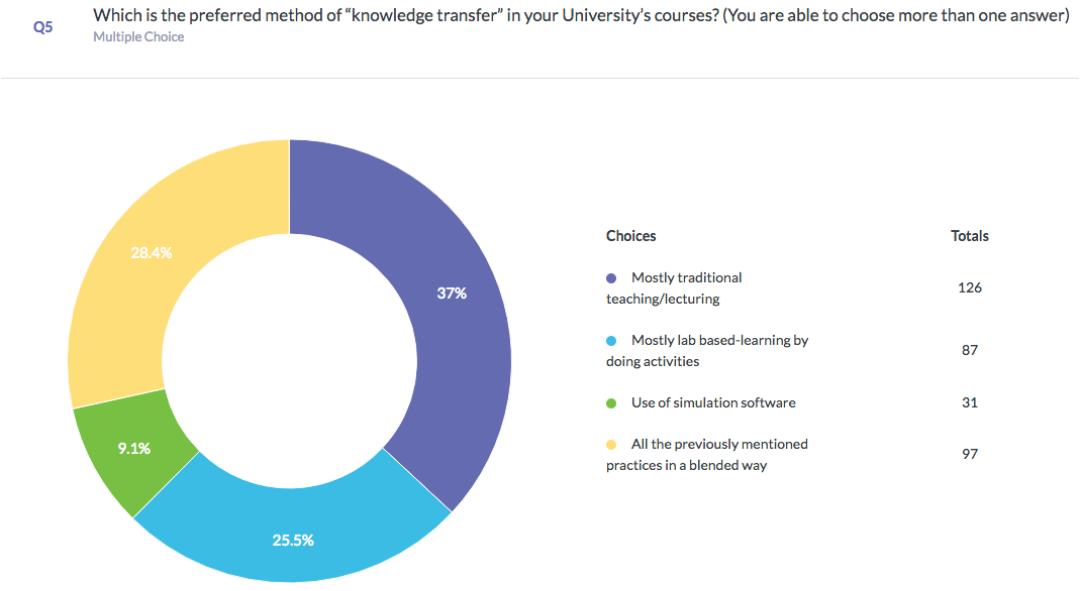

Figure 6. Participants' perception on the knowledge transfer model applied at their universities.

What comes as a really disappointing and unpleasant surprise is the statement of almost one third of the participants (37%) that in their universities' the preferred method of "knowledge transfer" is mostly through lecturing and traditional teaching schemes. Thankfully, another 28.4% confirms that they are involved in learning by doing activities that take place in lab environments and/or with the use of simulation software. More than half of the participants (50.4%) rate the technical infrastructure of their universities' lab as "sufficient" and a significant 24.4% as "very good".

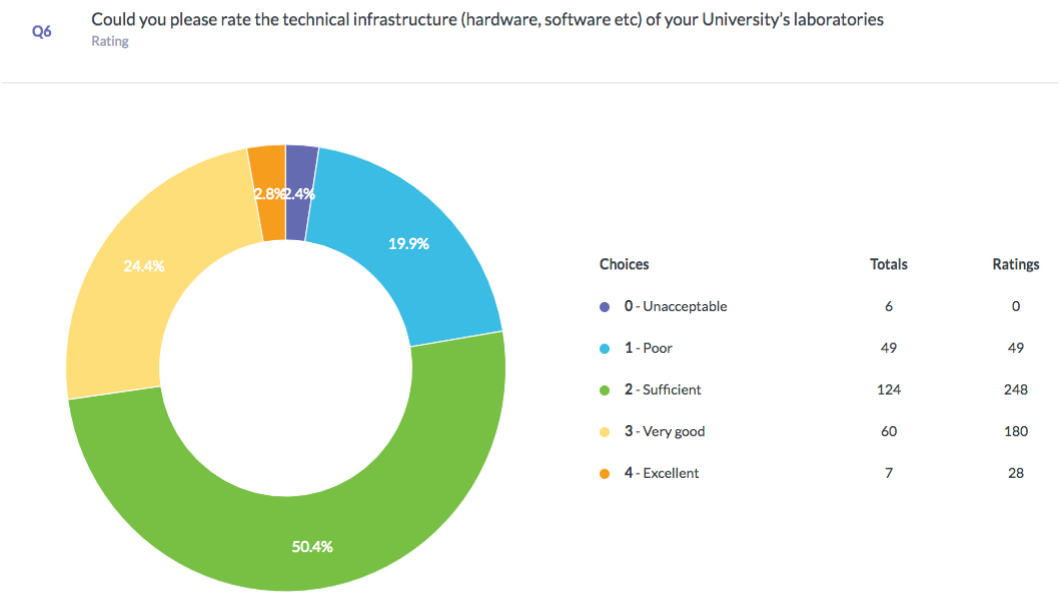

Figure 7. Participants rating of the technical infrastructure of their universities.

Regarding agile manufacturing and development practices, 167 participants (67.9%) state that they already know what this term refers to but only 48.4% have been involved in the development of products and/or software using agile principles and methodologies in the past.

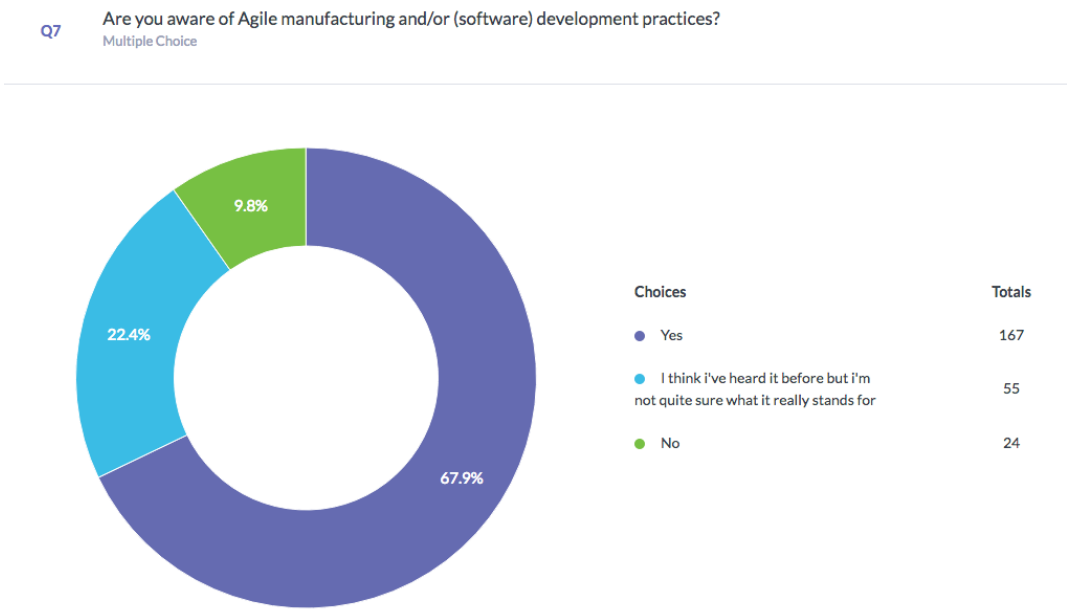

Figure 8. Participants' familiarity with agile manufacturing approaches.

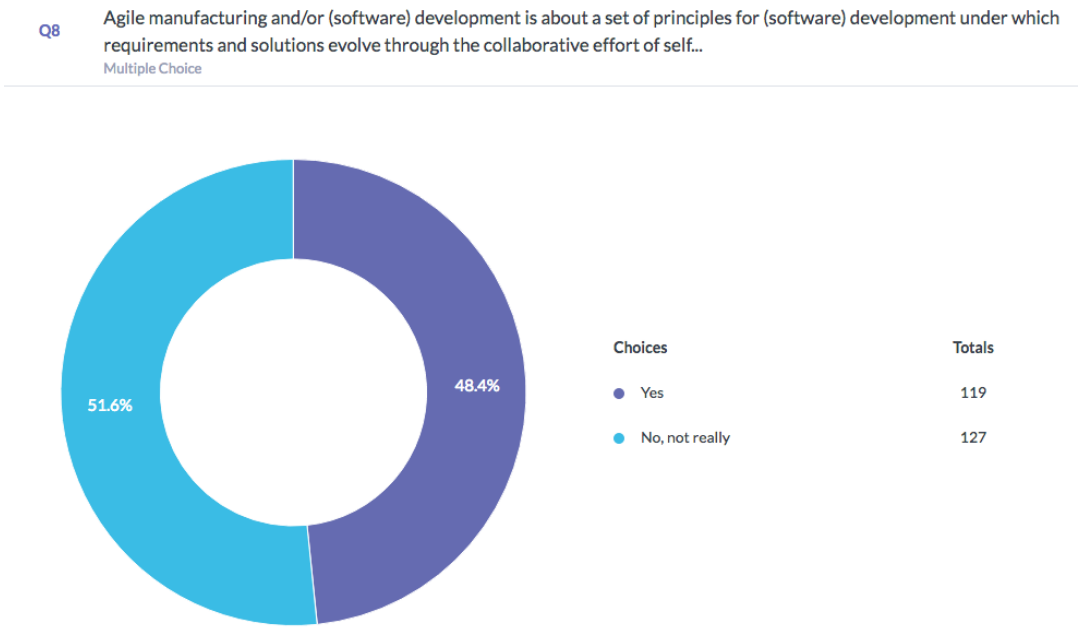

Figure 9. Participants' awareness regarding agile manufacturing.

Moreover, according to the participants the elements that are particularly linked to agile practices are "response to continuous change" (17.9%), "con-

stant customer collaborations and engagement" (17.3%), "delivering working products" (14.1%), "customer satisfaction" (12.8%) and "serious evaluation of interactions" (11.7%).

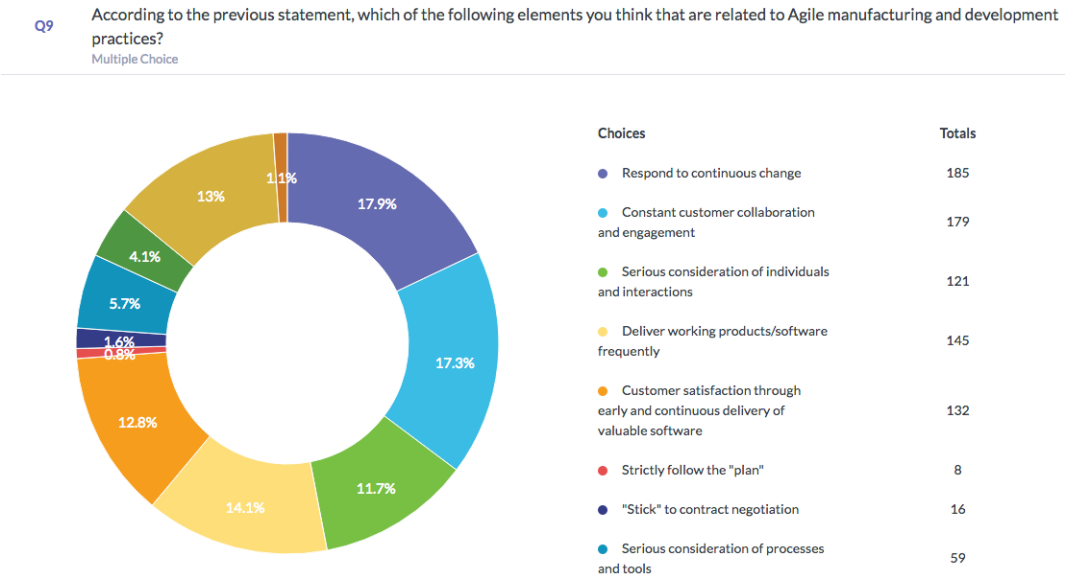

Figure 10. Participants' opinions on which elements are related to agile manufacturing and development practices.

In addition, 42.7% of the participants attend universities that offer specifically designed courses that teach agile processes but, surprisingly enough, less than half of the students (43.5%) have attended any of these, a percentage that is totally in line with the 68.3% that seems to have never been involved in agile related short courses in their free time.

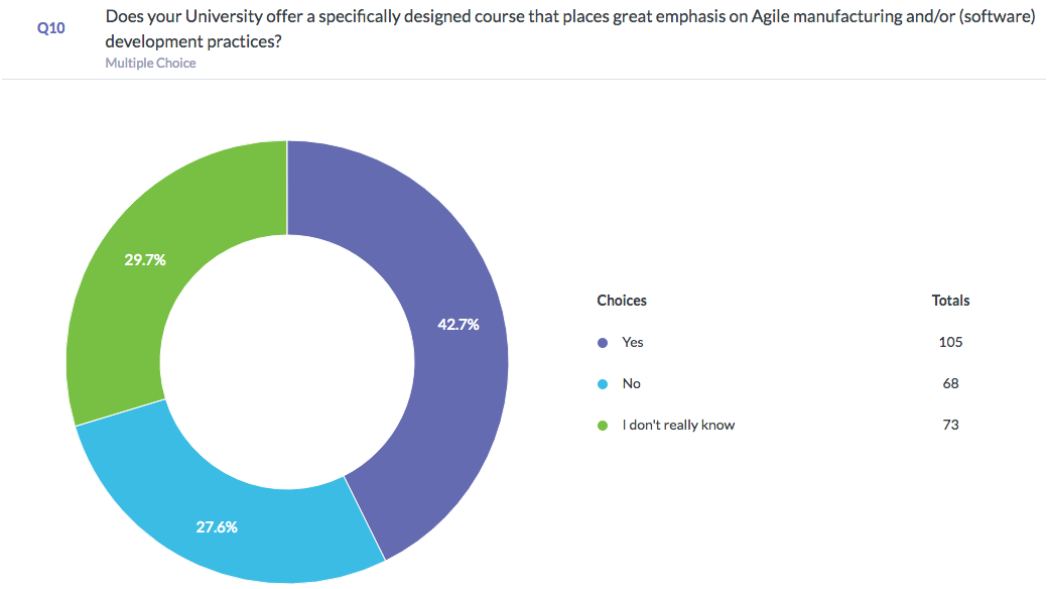

Figure 11. Participants' responses on whether their university offers courses related to agile design.

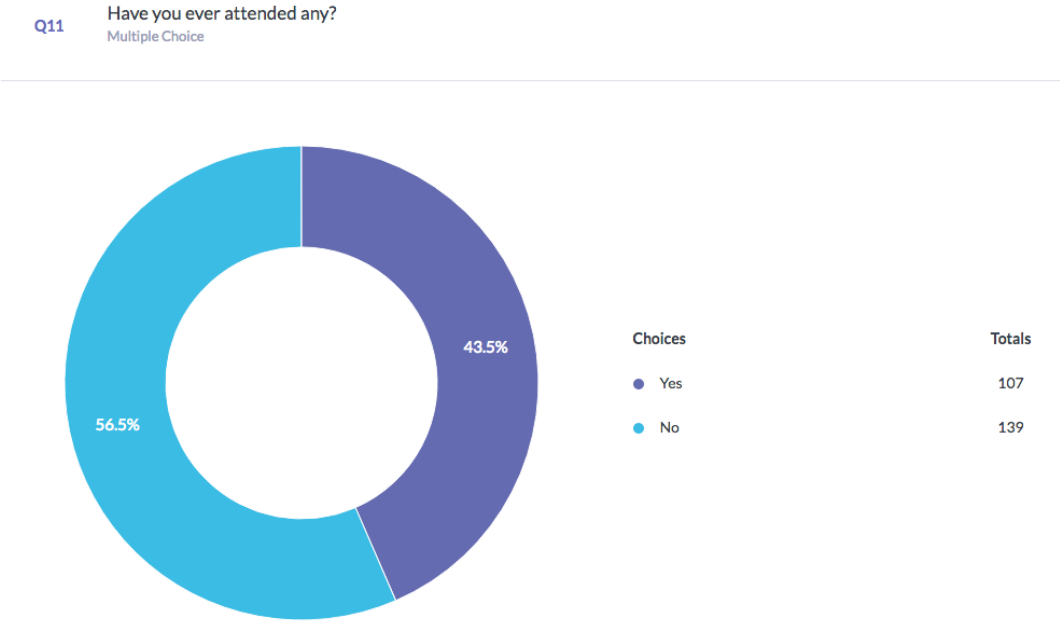

Figure 12. Participants' response on whether they have attended courses on agile design.

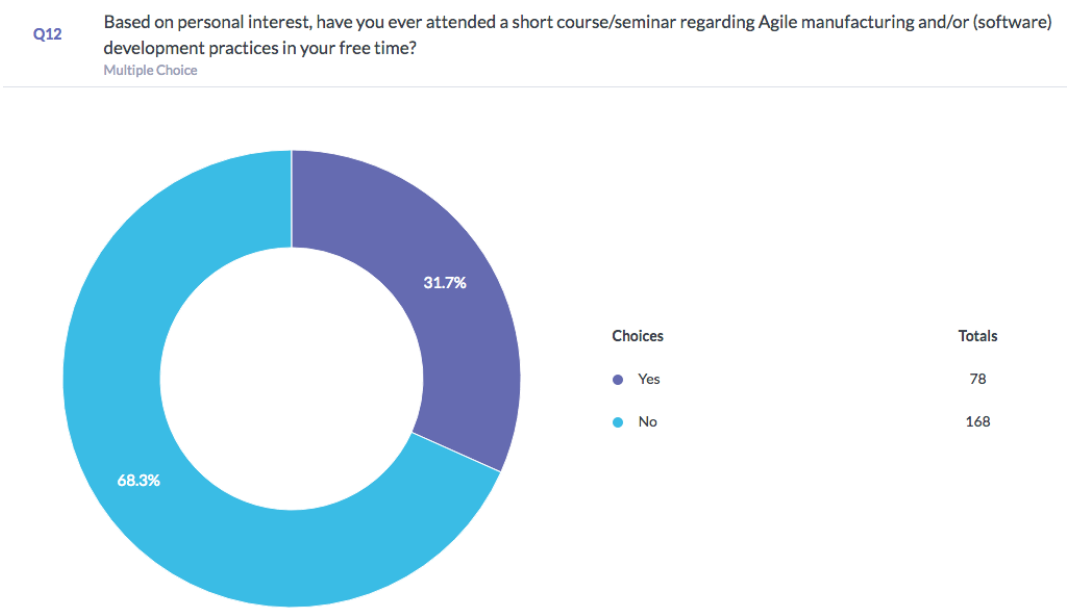

Figure 13. Participants' responses on whether they have attended seminars or other informal training related to agile design.

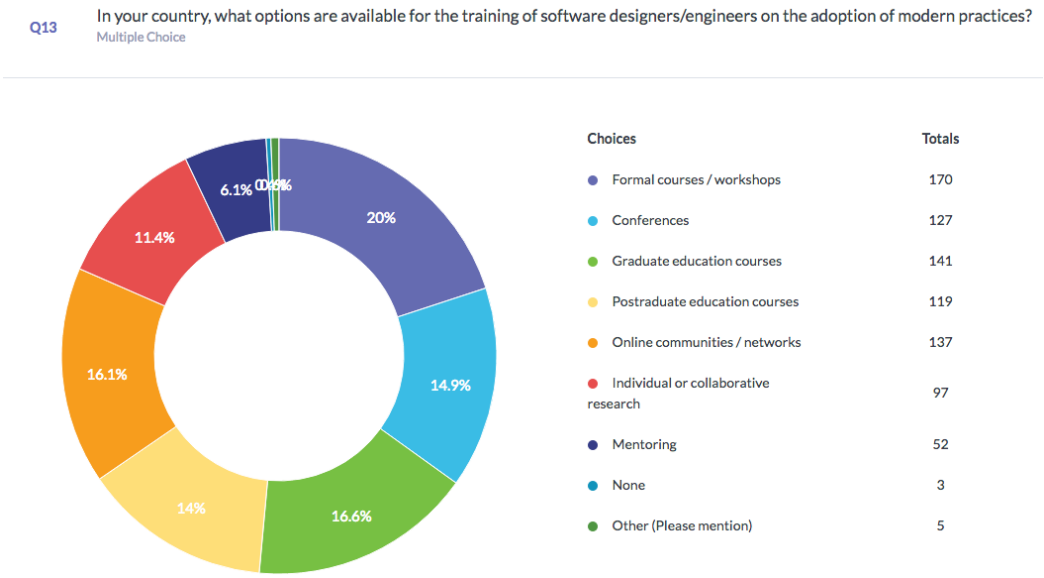

Figure 14. Participants' perceptions in relation to training opportunities and options in formal and Informal courses on agile manufacturing and modern practices.

Regarding the available formal and informal options for the training of designers and engineers on the adoption of modern agile practices, the answers are quite balanced and cover a wide range of possibilities. Formal courses and workshops are the most popular choice (20%), while attending

undergraduate education courses (16.6%), conferences (14.9%), postgraduate courses (14%) and participation in networks and communities (16.1%), come very close in the preference list. The least preferred option seems to be mentoring activities at only 6.1%. Interestingly, the majority of the participants (58.1%) has taken part in many of the aforementioned learning activities.

Most of the participants (25.3%) seem to agree that active learning scenarios inspired by real life circumstances are the most appropriate way of learning about agile processes, while, as expected, learn by doing play, hands-on games, constructions and activities come second in the preference list with a total score of 41.4%. Luckily, few participants (a total of 15.7%) value the efficiency of traditional teacher-oriented, drill and practice activities.

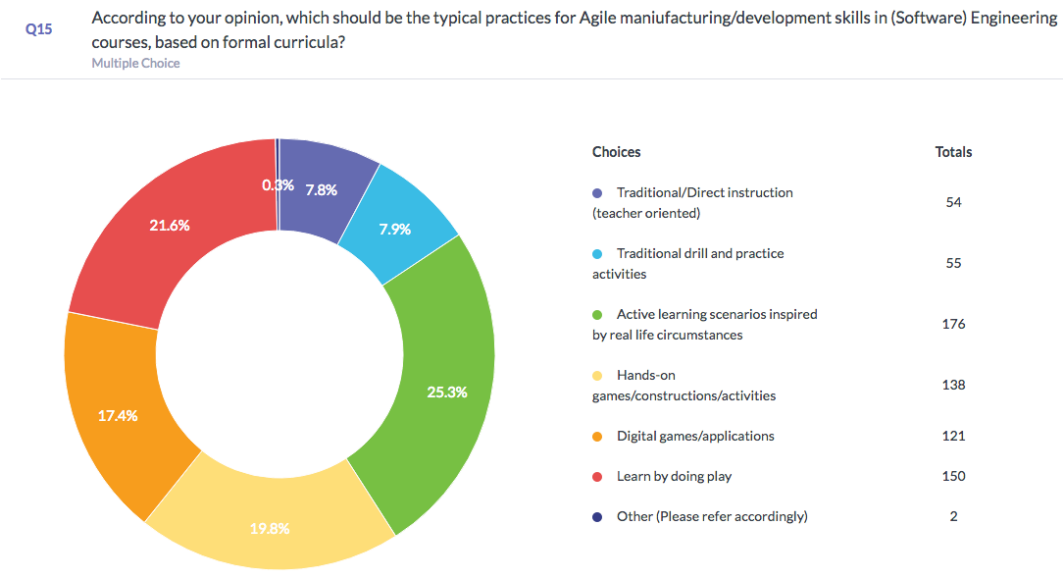

Figure 15. Typical practices for agile manufacturing/development skills in Engineering courses.

Last but not least there is a question about how many of the participants are aware of the term “serious games” and it seems that most of them (54.9%) already know it while a mere 17.1% declare total ignorance. It also seems that those who already have a clear idea of what a serious game is appreciate the educational impact of such tools and the percentages regarding

the benefits are equally distributed as it is clearly shown in the following graph.

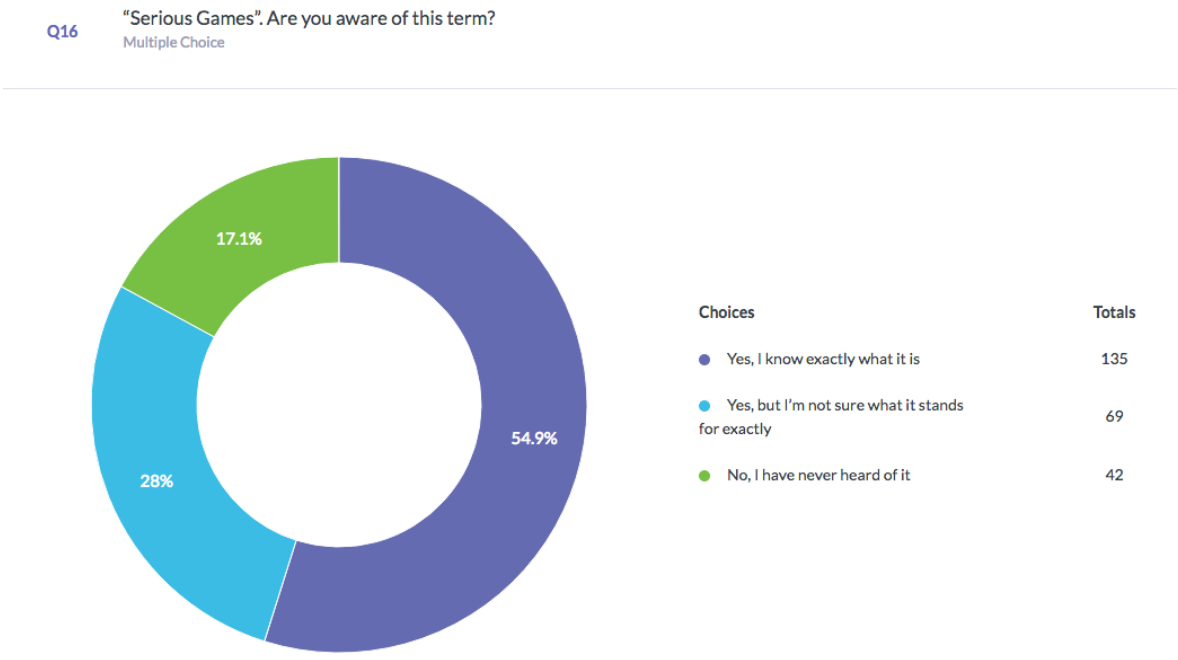

Figure 16. Participants' awareness of the term "serious games".

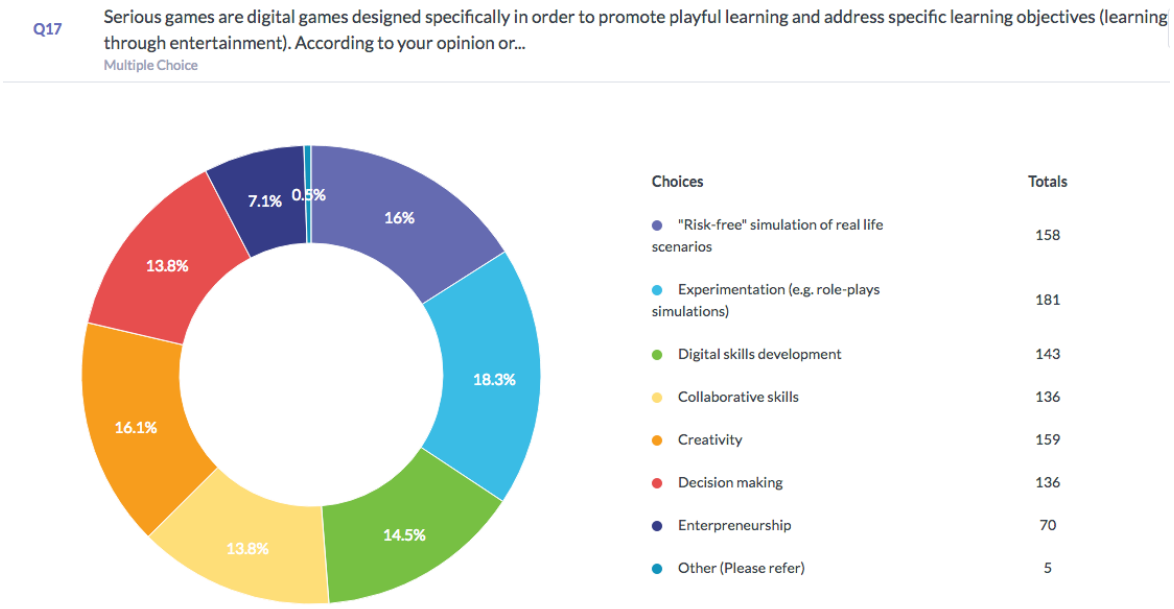

Figure 17. Participants' awareness of the potential benefits of serious games in learning.

11. LEARNING REQUIREMENTS DEFINITIONS

The content of the LEAP pilot application must keep pace with the needs that higher educational students confront. These students are about to enter industry and they must be prepared to act effectively in this realm. Through the agile methodology, they are expected to understand that design is developing. Furthermore, they will grasp the idea that this approach is far from the design up-front that the classic engineering process compels.

First of all, students are will be exposed to brainstorming since through agile design processes they are forced to come up with ideas that apply to the customers' needs. The students come face-to-face with the first prototype of the specific project and they should be aware of the fact that the customer may actually not have precisely described their needs. This is the main reason why they should be patient and prepared to make a second prototype, a third one and so on. Students will be exposed to SCRUM "sprints" and to daily meetings. As a consequence, they will learn how to be a part of teams and collaborate efficiently. During the "sprints" students will put the ideas on a whiteboard instead of discussing them in preparation for the design of a first release of a deliverable. This process will be repeated in several iterations. Students will introduce deliverables to the "customers", who will decide whether they accept this specific release or not. In case they do not, the students will go back to the whiteboard and start over.

Students will learn how to be disciplined to the agile methodology, as these principles are against the predetermined ones of classic engineering. They are also expected to conceive the fact that agile is not a panacea for everything. For instance, agile is not an appropriate approach for a blueprint, such as a traditional production line.

What is more, the LEAP serious game will help students develop qualities and competences that contribute to them being prepared to face a future risky situation in terms of their career. The scenarios to be presented in this

serious game are beyond the obvious and they are applied to different contexts. This serious game will not only give the practical experience but it will also allot oriented knowledge that aims to their better transition in their future workplace by addressing their lack of industrial experience. The game will provides insight into agile processes. Through specific contexts, students will get the actual feeling of taking on responsibilities.

This section of the report is expected to clarify the learning requirements that students are expected to achieve and afterwards the ones the professors are expected to gain. Firstly, the scholars' learning requirements are about to be presented. The requirements are documented using the IEEE standard format.

11.1 Learning requirements for students

ID: LR-S01	
Title:	**Acquaintance with the agile methodology and its applicability.**
Description:	Students are expected to experience the principles of agile through this serious game and fully understand what agile is actually about. They are expected to apply the agile approach so as to cope with difficult situations in terms of many significant sectors and fulfil specific workplace tasks.
Justification:	Agile is a preeminent, innovative, effective and up-and-coming methodology, which appears to be applicable to many sectors. This serious game is built according to the established agile principles.
Dependence:	None.

ID: LR-S02	

Title:	**Students' even introduction to the industrial processes.**
Description:	This serious game helps higher educational students to get in the industry processes evenly. Students are expected to grasp that hard knowledge is not such a significant qualification towards their success, since it changes rapidly. It mainly teaches scholars how they can learn on their own and the necessity of being flexible and adaptable towards breeding ground.
Justification:	Industry is a rising sector that requires multiple qualifications and this serious game is about to equip higher educational students to be proficient and ready to excel at their professional occupation in industry. Students that are about to use this game will act as if they work in the industrial sectors, since the graphics will simulate an industry.
Dependence: **Interdependence:**	LR-S01. LR-P02, LR-P03, LR-P09.

ID: LR-S03	
Title:	**Deci-thinking – Critical thinking.**
Description:	Scholars will use this serious game and they will be met with scenarios that will change their requirements over and over again. In every single moment, there will be a necessity of making decisions about how they will handle a hindrance that appears. Resulting in a decision, students should get through assumptions and

	they should assess the feedback they get so as to get the whole picture of the situation. As a result, they are expected to come up with an idea that will help them decide their next step. They will develop critical thinking too, since they will be forced to understand which resolution will be beneficial to their team.
Justification:	There is a great necessity of developing attributes such as deciding-thinking and critical thinking, as those are indispensable towards their evolving career. In the students' future workplace, ending up in a beneficial decision is a mandatory and crucial situation they will constantly find themselves in. This serious game is designed to simulate situations that incessantly require deciding-thinking.
Dependence: **Interdependence:**	LR-S01. LR-P04, LR-P05, LR-P06.

ID: LR-S04	
Title:	**Problem deconstruction and redefining the prototypes rapidly having as an aspiration their reapplication.**
Description:	Students are trained to deconstruct a problem into smaller components and they will try to make up a full-back execution so as to solve every component prosperously. They also learn that the most efficient method of succeeding is not to throw away their first prototype. They will make a prototype by making decisions that are beneficial to the situation of the game

	and afterwards they will have to work on this in order to adjust it to the current requirements. They are going to be ingenious so as not to waste time by throwing away their previous occupation and start over.
Justification:	As a consequence, scholars will digest that one of the main ideas that applies in agile methodology is to re-use the work you have already done and upgrade it by using the feedback and the previous prototype. Last but not least, they will learn the necessity of breaking-down a problem into smaller constituents and the re-quirement of solving each of them separately.
Dependence: **Interdepend-ence:**	LR-S01, LR-S02, LR-S03. LR-P06, LR-P07.

ID: LR-S05	
Title:	**Flexible thinking and adaptability to change.**
Description:	Students are exposed to scenarios in which new re-quirements come up unexpectedly. They start provid-ing that they are expected to achieve a goal and after a while they have to handle situations in which the es-sential facts have already changed. They also have to understand how much it will take for a requirement to be accomplished and of course they should make up their minds with the best prioritization of the require-ments given.
Justification:	Scholars grasp the idea that in a workplace nothing is fully predicted. As a consequence, they have to be

	flexible, insightful and they should go beyond the obstacles and always find a way to overcome difficulties and move on. They should keep in mind that the best way to succeed is to think positive and try to embrace the changes such as Agile does.
Dependence: **Interdependence:**	LR-S01, LR-S02, LR-S03, LR-S04. LR-P06, LR-P07.

ID: LR-S06	
Title:	**Collaboration, teamwork and building relationships with the customer.**
Description:	Students have to cooperate with others within the team, since they will not work alone. This serious game provides scenarios in which the students should learn how to coexist with others so as to complete a specific goal. They will also have to build relationships with their customers in order to keep up with their needs.
Justification:	Workplace tasks demand cooperation with others, since the requirements are difficult to be accomplished by one individual. Scholars experience situation where they should be open-minded and receptive to others' ideas. Building a good relationship with the customers will help students to be close to them in the near future and satisfy their requirements gradually.
Dependence:	LR-S01, LR-S02, LR-S03, LR-S05, LR-S07.

ID: LR-S07	
Title:	**Prioritization of tasks and allocating competences**
Description:	In this serious game students deal with a variety of tasks that have to be done successfully. They will try to prioritize them so as to have better results. Furthermore, they will be about to learn how to allocate competences. They will even experiment in assigning various roles.
Justification:	Students learn how to prioritize. This is a significant requirement that is demanded in their future career because the tasks that appear may not be accomplished at once and concurrently. They are also expected to have a leading role in terms of a team and organise the tasks properly. By placing themselves into many different roles, they will learn to respect every single post and stop underestimating others that may have a less leading roles in their workplace, as they'll understand that every post contributes to the accomplishment of a goal.
Dependence: **Interdependence:**	LR-S01, LR-S02, LR-S03, LR-S04, LR-S05, LR-S06 LR-P09.

ID: LR-S08	
Title:	**Estimating how long it takes for things to be implemented and planning**

Description:	Students will face situations in which they will have to estimate the duration that each task has and understand if the time needed is provided and plan the order that the tasks will be completed.
Justification:	They develop critical thinking and are flexible enough to make the appropriate changes to the timeline. It is very important to demand feasible tasks that are having the necessary time and organise tasks more efficiently.
Dependence: **Interdependence:**	LR-S01, LR-S02, LR-S03, LR-S05, LR-S06, LR-S07. LR-P04, LR-P06.

ID: LR-S09	
Title:	**Successful trials and error handling.**
Description:	In this serious game, scholars come up with trials that may be either successful or not. They will learn in a safe environment how to cope with these situations.
Justification:	Students will face difficulties in their future workplace. There will be cases where the will make trials that will be proven to be effective, but there will also be in situations where they will find themselves in error handling. This serious game enables them to handle errors and never give up. The point is to understand why they get wrong and try to be more efficient the next time.
Dependence: **Interdependence:**	LR-S01, LR-S02, LR-S03, LR-S04, LR-S05, LR-S07, LR-S08. LR-P08.

ID: LR-S10	
Title:	**Learning in a supportive and harmonious environment**
Description:	Students learn and acquire knowledge in a virtual reality, namely in a safe environment without any risks of underachievement. They feel sheltered and they act as if they play a game and they will be able to experiment.
Justification:	By using this serious game, students are expected to develop self-confidence and self-control and understand the significance of being protected by being exposed to a wide range of educational contexts that will be elaborated below. They will understand the difficulties they will face in their future career and be ready to keep calm and deal with them.
Dependence: **Interdependence:**	LR-S01, LR-S02, LR-S09, LR-S11, LR-S12. LR-P05, LR-P09.

ID: LR-S11	
Title:	**Concealing the computational complexity.**
Description:	Students are exposed to a serious game that makes everything seem simple. They are not expected to understand neither the complexity of this game nor the complexity of the actual workplace situations.
Justification:	Scholars are expected to grasp the idea of existing in a workplace. They are anticipated to have fun but also developing significant attributes at the same time.

	They will not understand the difficulties of creating these graphical interfaces or in the real scenarios where you are face to face with the customers or even the boss.
Dependence:	LR-S02, LR-S10.

ID: LR-S12	
Title:	**Preparation of their transition into the workplace environment.**
Description:	Students who are about to use these serious games, will develop significant skills that will equip them to their future transition in their workplace.
Justification:	This pilot serious game enables the scholars to be ready to start their career, not only by simulating the workplace environment and many feasible scenarios that they may find themselves in but also by helping them endure some difficult situations that will appear to be full of stress and anxiety. Students might not understand the extent of the actual difficulty they will face, but the will get the whole picture and this is a crucial factor towards their evolving career.
Dependence: **Interdependence:**	LR-S01, LR-S02, LR-S03, LR-S04, LR-S05, LR-S06, LR-S07-LR-S10. LR-P03, LR-P05, LR-P09.

ID: LR-S13	
Title:	**Running on all platforms.**

Description:	It is expected that students are about to use this serious game in every platform.
Justification:	There's a great necessity of applicability in every platform so as to be easily used by students, without having second thoughts. Furthermore, its portability is of a great importance, too, since the scholars have to spend a great amount of time studying outside their houses such as in libraries and this serious game should be available to them, wherever they are. When they feel that they need to take a break, they can play this game and can have fun and develop skills concurrently.
Dependence:	None.

ID: LR-S14	
Title:	**A little storage capacity is a prerequisite.**
Description:	Students are not always capable of having a great storage capacity. They may have laptops or even smart phones and there's a great possibility that they'll use this game via these means. So, a little capacity is something that actuates them use this game without getting bored while waiting for the application to be loaded. It is very significant not to spend time waiting for the game to move on to the next still of the game, since their interest will be eliminated and they will not pay the appropriate attention that the game deserves.

Justification:	This serious game is expected to require little storage capacity so as to be loaded easily and without appearing any lag during the changes of the stills of the game.
Dependence:	None.

ID: LR-S15	
Title:	**Extensive practicality to the engineering realms.**
Description:	This serious game will present a variety of scenarios that will approximate real ones in different situations. For instance, there will be a scenario of a warehouse management that applies the manufacturing sector. Furthermore, scenarios of software development, entrepreneurship will follow. Alternatively, there will also be scenarios that will illustrate the services engineering, such as the tourism, an urban planning or even traffic control. Another example that will be examined is the smart farming that will enable the user to have a more efficient farm that they were used to. Speaking of the smart farming, they will learn the best way of irrigation so as to have a beneficial farm that will give return on investment.
Justification:	Students will understand that everything must be weighted when it comes to business, and specifically to engineering. There are methodical ways that can lead them to success. All in all, the main idea of using these scenarios is to have a deeper knowledge of confronting situations when not ready and implement the skills they develop to come to the best solution.

Dependence:	LR-S02, LR-S03, LR-S04, LR-S05, LR-S06, LR-S07, LR-S08.

11.2 Skill building requirements for instructors on deploying ICT

The following section is about to demonstrate to the professors of the universities the necessity of developing their professional training skills so as to improve themselves, keep updated towards the rapid changes of technology and take advantage of it to help the scholars evolve.

Technology keep amending continuously and students use it in their daily routine. By using this serious game, it is considered that professors will get the chance of approaching their students, they will be able to “speak the same language”. They will understand the students’ needs and this will be greatly useful to impart knowledge.

The professors’ learning requirements are discussed below.

ID: LR-P01	
Title:	**Easy incorporation to the scholar schedule.**
Description:	Professors have created a schedule that contains a timetable with the modules that they expect to teach their students. In case of using this serious game, this one should be easily adapted and interwoven to the courses’ needs and the professors should be able firstly to understand its use by themselves and secondly to explain it to the students.
Justification:	Restricted time of the university courses. The modules have specific duration and this is the main reason why this game should be easy to be integrated in these courses.
Dependence:	LR-P06, LR-P07, LR-P08.

ID: LR-P02	
Title:	**Understanding the necessity of emerging digital applications that are interwoven to the industrial realms into scholar schedules.**
Description:	This game enables the professors to understand the extent that digital applications have emerged towards their lives and their scholars' ones. By allowing the latest to use this serious game, they contribute to their future engagement to the use of technology as a means that will help them keep up with the rapid changes that exist in their workplace nowadays.
Justification:	As a result, professors will benefit the students by providing them openness and receptivity to new ideas or tools. This game will raise professors' awareness on the evolution of the pedagogical methods they use and it will provide them the opportunity of experimenting in simulating environments of an engineering workplace and stay away of the traditional predetermined methodology of teaching.
Dependence: **Interdependence:**	None. LR-S02.

ID: LR-P03	
Title:	**Understanding the necessity of the connection between the acquisition of knowledge and its implementation in the industrial realms.**

Description:	Professors should understand that there is a great necessity of connecting the acquired knowledge, namely the theory, with its practicality. During the scholar courses, students learn about specific sectors and their knowledge is far from the one needed when they work. Professors should understand and later explain the students that everything they learn is fundamental and that by using this serious game they will have the opportunity to apply everything they learn.
Justification:	Professors are expected to perceive the need of using this game since there will be a connection that will enable the students grasp what they will face in their future workplace. It is highly significant to apply the acquired knowledge.
Dependence: **Interdependence:**	None. LR-S05, LR-S10, LR-S12.

ID: LR-P04	
Title:	**Promotion the development of high quality knowledge among the scholars in a smooth way.**
Description:	By using this game, professors will achieve to promote high quality knowledge that will come from the students. The way this will happen is simple, as the students will confront this serious game as a game that will release them from their stress and the anxiety that an auditorium creates. They will feel like home and they will be open-minded towards new experience and ideas. Professors will promote the knowledge they have planned in a less

	tedious way and their courses will appear to be far more interesting.
Justification:	Professors will use this serious game effortlessly and their goals will be achieved in a more effective way. They will not spend their time of their modules meaninglessly, because this game will cover their needs and it will provide them with knowledge that will be more purposeful rather than what they could achieve via questionnaires.
Dependence: **Interdependence:**	LR-P06, LR-P07, LR-P09. LR-S03, LR-S08.

ID: LR-P05	
Title:	**Learning the necessity of raising students' motivation and encouraging creativity in problem solving activities.**
Description:	Professors have experienced teaching and they have developed their highroad. Most of them want the safety of this tried and true methodology. They avoid upgrading their methodology and this is the main reason why they lack of innovation and creativity. They don't encourage students to broaden their horizons. Instead, they cleave to their own methodologies, refusing to keep up with the latest development of the technology.
Justification:	Professors are expected to understand that there is a great need of raising scholars' attention and motivation and this cannot happen by continuing their highroad.

	Through this serious game, they should perceive the necessity of breaking the mould and adopting innovative methods which will encourage students to see through a different prism the whole learning process. What is more, the should figure out what changes they will have to make, so as to help students accumulate usable knowledge which scholars will accommodate to their workplace needs.
Dependence: **Interdependence:**	LR-P03, LR-P04, LR-P06, LR-P08. LR-S03, LR-S10, LR-S12.

ID: LR-P06	
Title:	**Developing critical thinking professor skills.**
Description:	Professors need to develop analytical and critical thinking. In this way, they will learn how to be prepared to recognise which learning models are innovative and should be adopted or even replace the previous ones. Through this serious game, professors learn to introduce enterprising patterns to the students.
Justification:	By developing critical thinking, professors are expected to become more efficient in their auditorium and implement the existing formal curricula in more inventive ways, which will capture the scholars' attention. Most of the times there are limited resources and this is the main reason why they hesitate to foster critical thinking. This game anticipates that professors will get rid of their lack of self-confidence and they will encourage scholars to

	analyse situations and learn how to solve even the most complicated problems methodically.
Dependence:	LR-P01, LR-P04, LR-P05, LR-P07.
Interdependence:	LR-S01, LR-S03, LR-S04, LR-S05, LR-S08.

ID: LR-P07	
Title:	**The necessity of a perpetual professional development.**
Description:	Professors will use this serious game and will face agile and its applicability. They will perceive the need of redefining prototypes so as to be reapplied and they will make the connection between the methodology they use and the methodology they want to achieve. In this way, they will understand the necessity of improving themselves so as to keep up with the latest knowledge and be up to date. By improving themselves they will require from their students to do the same and they will provide them an incentive to do so.
Justification:	Professors are expected to understand that the key to succeed and last over years is the self-development. Through this serious game, they will grasp the necessity of their ongoing development that will transform them into more efficient and erudite professors. They will broaden their horizons, and their evolution will be reflected to their students' evolution. This is how the professors will ensure that they will stay in their jobs in the long run and this can

	be explained as the return of spending their whole life by studying and developing lifetime skills.
Dependence:	LR-P01, LR-P03, LR-P04.
Interdependence:	LR-S01, LR-S04, LR-S05, LR-S12.

ID: LR-P08	
Title:	**Professional networking organised by the professors.**
Description:	This simply means not only peer cooperation in terms of the education, but also interconnection between professors and scholars. There will be a know-how exchange of both ideas in terms of education. Students will benefit from the professors' expertise and professors will benefit from the openness and the enterprising ideas of the students. Both of them will develop themselves and this can be achieved through this serious game.
Justification:	It is expected that the professors will be receptive to new ideas as well. Both sides will be exposed to lucrative cooperation. They will be able to understand the different facets that the students see and through this different prism, they will create a network that will benefit both sides.
Dependence:	LR-P01, LR-P03, LR-P04, LR-P05, LR-P06, LR-P09.
Interdependence:	LR-S03, LR-S10, LR-S12.

ID: LR-P09	
Title:	**Perceiving the level of the scholars' knowledge and their digestion towards a specific scholar course as compared to other universities' students.**
Description:	Professors that work in a variety of universities are about to use this serious game so as to evaluate if their students benefit from their teaching methodology.
Justification:	Professors are expected to use this serious game to scholar courses which are relevant to its content. As a consequence, they will let the students implement everything they will already have learnt. It will be apparent if the scholars integrate the knowledge provided with the specific methodology. If not, professors are expected to be receptive to develop their learning methods innovatively, so as to increase their effectiveness. This will be a way of self-evaluation for the professors and they should be open-minded to this idea, since the will be able to take advantage of this result and understand if they are moving to the "right direction" in terms of the pedagogical methodologies.
Dependence:	LR-P04, LR-P05, LR-P06, LR-P07, LR-P08.
Interdependence:	LR-S02, LR-S04, LR-S05, LR-S10, LR-S11.

12. SERIOUS GAMES FOR BUILDING AGILE AND LEAN SKILLS

Serious games constitute a major emerging technology that is rapidly gaining mainstream educational use recently and it is expected to become even more popular (De Freitas, 2013; Johnson et al, 2014). The highly engaging and motivating character of such games bolster up great potential to support immersive, meaningful and situated learning experiences. In addition, serious games constitute a relatively new approach to training and education in a wide range of contexts for international organizations such as the U.S. Department of Defence, the U.S. Department of Homeland Security, NATO (North Atlantic Treaty Organization) and many more. Although serious games are often proposed as stand-alone solutions, they can also serve as entry points into a comprehensive training pipeline and serve a primary purpose that goes beyond the aspect of pure entertainment. In the case of LEAP, the implemented serious game serves as a tool for developing students' agile skills and inspiring agile practices in order to effectively link higher education engineering to industry.

12.1 Serious Games. What are they all about?

According to de Freitas (2013) there are two main confusions around games for learning with the first lying in the amalgamation of leisure –fun- games and educational –serious- games while the second confusion has to do with the myriad of definitions surrounding games, which has led to different terminologies being used even within the same context of use. As far as the conflation between leisure games and educational games is concerned, it can be argued that this comes as a natural and understandable confusion since the terms for both are used synonymously, however this leads to misconceptions and ineffective use of leisure games in the classroom. In fact, such misconceptions trigger negative feedback on any use of games in education for two reasons. One the one hand, leisure games may be used in learning contexts as a relaxing break, which however does not respect any

sound learning design. Secondly, game-based learning may need a different pedagogic or learning framework in order to be used effectively.

Computer games for educational purposes have been present mostly in academic computer science courses during the 1960s, with “Spacewar” being the first computer game to be developed at MIT and arguably it was one of the first games to exhibit learning opportunities (Herz, 2001). By today’s standards, games are developed on games engines often without the use of programming languages but with the use of editing tools and software development toolkits and can be played on various platforms such as personal computers, games consoles, mobile-handheld devices and phones making use of mixed interfaces that can be used flexibly and interchangeably with other ICT tools and devices, e.g. social software, to support many different activities.

No matter what their specific features are, digital games with a potential educational twist can be briefly summarized in the following typology:

- **Educational computer games**. This refers to applications that have the characteristics of video games. While they may not be designed specifically for instructional purposes, they can help students engage in immersive learning experiences for delivering specified learning goals, outcomes and experiences.
- **Online games**. Massively multiplayer online role play games (MMORPGs), massively multiplayer online games (MMOGs), massively multiplayer online real-time strategy (MMORTS) are all online games that have become more widely used since their emergence as multi-user dungeons / dimensions (MUDs) during the 1980s. Thanks to broadband access to the internet and the higher level of interactivity secured by modern technologies they have become even more popular. Such games include either plain text-based environments or involve complex graphics and virtual worlds that are used by large numbers of players at the same time.

- **Digital simulations**. Virtual reality (VR) systems essentially introduce a way of modelling a real-world situation on a computer. Aldrich (2004) argues that simulations may be defined as non-linear exploratory environments. Nevertheless, the relationship between games and simulations has been close and even when VR systems were being pioneered the power of immersive environments for learning was already recognized especially for instructional purposes in various contexts such as astronauts' training, military operations design and practices and so forth.
- **Serious games**. This term refers strictly instructional video games that promote and support game-based learning or computer applications that have a challenging goal and they are fun to play and engaging. They integrate gaming elements, including scoring mechanisms, levels of difficulty, social recognition of achievements, unlocking of new content based on success, assumption of roles and more. These gaming elements are exploited for supplying the user with skills, knowledge or attitudes useful in real life. During the 1990s and the multimedia revolution the word "edutainment" became very popular in the growing PC market and described a concept that could be summarized as "education through entertainment" (Michael & Chen, 2006). On a second thought, the definitions of edutainment and serious games seem to refer to the same context. While the term "serious games" was coined the by Serious Game Initiative in 2002 in the USA and while there are diverse definitions of what a serious game really is, it can be generally defined as "a game in which education (in its various forms) is the primary goal, rather than solely entertainment" (Michael & Chen (2006). In 2005 Stokes defined serious games as "applications that are designed to entertain players as they educate, train, or change behaviour". No matter how many definitions are introduced, one main reason why such games are considered so effective for learning is their ability to induce a

> “flow experience”, a pleasantly perceived experience and a state of full immersion in a ludic activity. Playing serious games generally excites and involves the user while ensuring the acquisition of knowledge even in a “stealth mode” (Susi et al, 2007). Unlike traditional teacher centred learning environments serious games facilitate learner-centred approaches and support experiential learning by providing students with concrete experiences and active experimentation.

The aforementioned different terms stem from the fact that games are by default multidisciplinary, they all share the aspect of play and very often facilitate the general process of learning in immersive worlds that have a straight connection with the concept of “microworlds” in the sense of the actual game-world and space. When it comes to educational contexts, it can be argued that the concept of “microworlds” was originally introduced by Minsky and Papert (1971) during their early work with Logo language and floor turtle at MIT during the second half of the 1960s. In that sense, microworlds are given domains or environments that include objects, artefacts and representations and can be potentially explored in a non linear and “open-ended” way by users-learners. Therefore, the exploitation of microworlds builds up the potential for learning in many vocational contexts particularly for developing scenario-based learning opportunities based on role-play, character identification and simulations that make learning more effective.

However, while simulations have a very long history of use within military, medical and business training contexts uptake in other educational areas has been slower. The military sector has been exploiting simulations and eventually serious gaming in order to support effective training since the early days of technology and computing and as such it has always used the latest equipment and training approaches to accelerate learning and most of all, reduce the high costs of traditional training methods. This consistent use and development of modern approaches provide serious evidence in

itself of the success of these methods to train military forces. More specifically, the US military has identified the effectiveness of serious games and has been quick to develop some of the most engaging examples of serious games for multi-players.

Particular examples of the trend of developing serious games for military education are Full Spectrum suit of applications (Full Spectrum Command, Full Spectrum Warrior) and America's Army (de Freitas et al. 2006) both for military use providing practice and training at the strategic, operational and tactical levels. Full Spectrum is a PC-based training aid that modelled the command and control of a U.S. Army Light Infantry Company in a MOUT environment. The user takes over the role of the Captain of a U.S. Army Light Infantry Company and interprets a five-part Operational Order (OPORD) for a given scenario, organizes his platoons, develops a multi-phase plan and coordinates the actions of approximately 120 soldiers during the engagement stage.

Figure 18. Examples of Serious Games for military purposes.

The proposed scenarios were designed in conjunction with experts from the US Army in order to facilitate and enhance the development of specific cognitive skills, adaptive thinking, resource management, tactical decision-making and so forth. Another similar serious game for military purpose was, as mentioned before, America's Army that represents the first large-scale use of game technology by the U.S. government as a platform for strategic communication and the first use of game technology in support of U.S. Army recruiting. Originally released in 2002, the game has seen over 41 versions and updates until August 2013, all of which were financed by the U.S. government.

Serious games also appear in the education of healthcare professionals. This is of primary importance for patient safety. In most health related professions the use of new technology such as virtual reality, simulations and serious games can be extremely useful either because it improves the learning outcomes without putting in danger real patients. Furthermore, it keeps costs low because it is cheaper than traditional training methods that use cadavers or mannequins. Recently, the application of digital games for training medical professionals has been on a continuous rise and already plays a significant role especially in surgical residency training programs even though such educational tools do not yet constitute the norm in medical curricula. Among the most promising developments that have emerged is "Pulse!", a game developed by Texas A&M University, Corpus Christi, and funded by the Navy's Office of Naval Research in order to teach acute medical-clinical skills and familiarize students with the processes that take place in an emergency department so that they respond better to injuries sustained during catastrophic incidents. Highly interactive and detailed 3D world with accurate physiology models and fluid dynamics were used to simulate blood flow in the human body. Other related games are "ABCDE: Virtual Emergency Room", a game that intends to teach basic resuscitation skills, "Air Medic Sky One", that teaches the basics of patient safety, teamwork, and personal stress management, the latter via a simple biofeedback device

connected via a USB. Another fine example is “Clinispace” that offers immersive 3D virtual environments in a web-based application and enhances residents’ and nurses’ training experiences for many typologies of emergency patients. The player can play alone or in teams and the game supports many clinical spaces as well as interactive objects and medical instruments, while, with the addition of servers and cloud computing this serious game can be scaled to large class sizes.

Figure 19. Examples of Serious Games for healthcare purposes.

Another field that seems to take advantage of the potential of serious games is emergency management, corporate and government training within the range of which various scenarios may concern a number of different kinds of tasks and situations, such different types of crisis management; examples include dealing with terrorist attacks, disease outbreaks, biohazards, health care policy issues, city planning, traffic control and budget balancing (Michael & Chen, 2006; Squire, 2003). There are some fine examples of appli-

cations such as *"Virtual Borders"* in which, players test out different deployments of existing assets for border security. Various scenarios have been/can be created which gives the players opportunities to test out various strategies for securing the border. The game was developed in partnership with the U.S. Customs and Border Patrol to be an Operational planning and experimental too for the Secure Border Initiative. SBI staff would use Virtual Borders to test, validate and visualize operational plans, with an emphasis on the testing of different deployments of existing assets, and experimentation with proposed assets and sensor systems. Another interesting game is "vBank" which was developed in collaboration with the Federal Deposit Insurance Corporation (FDIC) in order to help improve fraud detection and financial risk assessment capabilities. vBank is currently being used to train auditors to uncover fraudulent activity by interviewing key bank personnel, examining bank records, and correctly following the money trail to its source.

12.2 Serious games for the development of agile skills.

As previously mentioned, one of the main objectives of the LEAP project is to develop a serious game that can be used in order to promote, within the framework of engineering higher education, lean and agile learning design linked to industry practices with the aim to facilitate students' effective transition into the professional world. Through the use of the serious game students will be encouraged to adopt industry roles, think critically, apply industrial process management and design cost and time effective solutions which ensure that the final product effectively addresses consumer needs while minimizing the deployment of resources. Prior to developing a serious game that would address the aforementioned issues the design team carried out a research on what related products already exist and to what extent they address lean and agile design processes. It became clear that although there are plenty of games and tools that can be used in order to help teams understand the "why" and the mechanics of being agile most of them are

non computer based kits that come in the form of classic table versions, printable sheets and materials and only a few are actual video games.

One of the most iconic games that, maybe kicked off the creation of more games that teach agile processes is the infamous “Beergame” or “Beer distribution game” that was originally invented in the early 1960s by Jay Forrester and a group of professors MIT as a result of work on system dynamics. Although the original goal of the experiential learning business simulation game was to research the effect of systems structures on the behaviour of people, the game can be used to demonstrate the benefits of supply chain management, collaboration in the supply chain and information handling and sharing. The game play is pretty straightforward and the object is to meet customer demand for cases of beer through the distribution side of a multi-stage supply chain while ensuring minimal expenditure on back orders and inventory. The game consists of four stages: manufacturer, distributor, supplier, retailer, with a two week communication gap of orders toward the upstream and a two week supply chain delay of product towards the downstream. In the board game version players cannot see anything other than what is communicated to them through pieces of paper with numbers written on them, signifying orders or product. The retailer draws from a deck of cards for what the customer demands and the manufacturer places an order, which, in turn, becomes product in four weeks. The game is played by teams of at least four players and takes at least one hour to complete, followed by a session of roughly equivalent length in order to facilitate the discussion and the review of the outcomes of each team.

Another board game that seems to draw its origins form “Beergame” is “Friday Night at the ER” which**,** actually is an experiential team-learning game, played on game boards at tables with four players per board. A detailed debriefing in which participants relate the simulation experience to their own work and gain insights for performance improvement follows each game play session. The plot of the game is about managing a hospital during a 24-hour period and eventually asking players to perform distinct functions

and to consider the value of collaboration and dependencies with each other. Each session includes 1.5 hours of game play followed by approximately 1.5 to 2 hours of debrief and discussion. In each simulated hour typical hospital activity takes place such as scenarios with patients' arrival, transfer and departure flow, department managers completing tasks, managing available resources, making decisions and eventually documenting results. Scenarios are pressured by time limits, quality and cost measures and interactions with peers and because of the fact that the game play is notoriously engaging, the participating teams are motivated to perform well. Group sessions may range from 4 to several hundred participants. After the end of the game, a program leader guides participants through an interactive debrief that includes exercises and rich discussion that usually surface insights and ideas.

The game was originally developed in 1992 by Breakthrough Learning, Inc., an American consulting and training firm and the initial purpose was to broadly teach people to think systemically and collaborate effectively in order to achieve system goals. Since then, the "Friday Night at the ER" game has been used for a broader range of learning objectives within diverse fields and by service organizations, manufacturing companies, government agencies, academic institutions and others in at least 30 countries.

Figure 20. "Friday Night at the ER" board game for teaching agile design.

Another common game that addresses agile practices is "Kanban Pizza Game"[xi] that focuses not only on the mechanics of the board and on the flow

in a pre-defined Kanban system, but also teaches how to get from an existing process to a Kanban system, how to visualize it and start modifying it. The game helps the participants to understand what Kanban is and practice some lean concepts in a safe environment outside of daily work and it takes at least one hour at the bare minimum while two hours is enough to cover the theory adequately and allow for reflecting and summarizing. The flow of the game consists of distinct stages such as the creation of an implicit process **(**it always starts where you are, from an existing process). At the beginning of the game, teams are encouraged to get to grips with the paper pieces and constraints by building as many pizza slices as possible and afterwards present a ready-made slice of pizza to the other teams and explain what goes into it. Then each team has to show the oven plate and explain how it works. There can be a maximum of three pizza slices in the oven at one time. Cooking time is at least 30 seconds. No adding or removing of slices while baking! Then the teams are asked to produce as many pizzas as they can while trying to avoid waste i.e. raw materials prepared but not used until time is up and announced by the coordinator of the game. At the end of the initial round the teams are introduced to the core practices of Kanban (Visualize the Workflow, Limit your Work in Progress, Manage the Flow, Implement Feedback Loops, Make Process Policies Explicit, Improve Collaboratively). After the engagement and introductory stage the teams are asked to put in use the newly established Kanban system for the next 4 rounds that gradually become more complex since new elements come into play. Examples of new elements include various and clearly different orders from customers, new ingredients that need special attention and “cooking” processes and so forth. The final step in the game is to visualize the process that is drawn on the tables using painter’s tape and create something that is closer to a real Kanban board. Teams are encouraged to look back at the game, draw the flow on a flipchart or whiteboard, including WIP limits, and make it look nice using paper materials and pizzas produced during the game. With the physical production of the pizza the workflow is

always present, and by drawing the workflow, teams create a representational model that can be used for reflecting on the whole process.

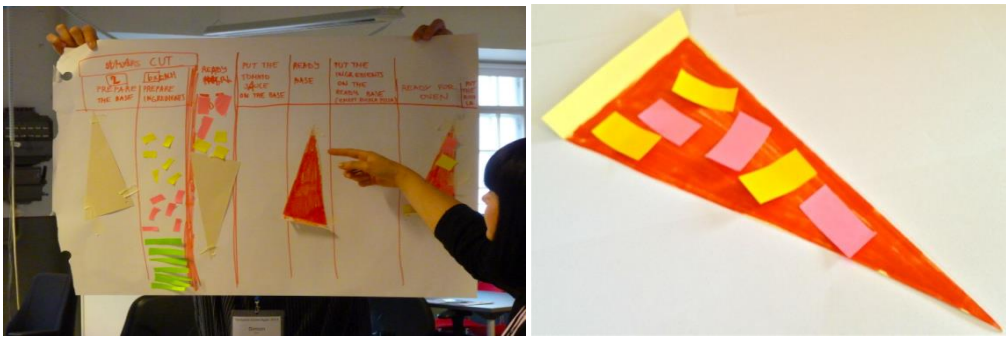

Figure 21. “Kanban Pizza” board game for introducing agile design processes.

One more common approach and tool to teach agile processes is **“**Lego4SCRUM”[xii] which involves teams that role-play and get hands-on product development within a time span of 1:40 to 2 hours of play using Lego. SCRUM trainer Alexey Krivitsky originally invented Lego4srcum and it is largely based on the Lego Serious Facilitation[xiii] methodology that extends the role of Lego bricks as a play toy to contribute to design thinking inside large organizations. In the SCRUM Lego® game, one or more teams work together with a customer or product owner, usually played by the coordinator and game master, to construct an environment like a city, primarily with Lego® bricks. The product owner begins by presenting a prioritized backlog of buildings he or she requires, and the teams help clarify the requirements. An estimation round is performed in order to help the teams size the buildings in terms of complexity. Teams then proceed by pulling items from the backlog, one by one and starting from the top, that they feel can be finished in a sprint of 7 minutes. The sprint begins when teams feel comfortable enough with the amount of work they have selected but are willing to try out their creations. After the first creative cycle, the product owner reviews the results with the teams, they discuss about the changes and specifications are clarified when a building was built incorrectly. A short retrospective can be done and the teams proceed with two additional sprints and finally a global retrospective on lessons learned.

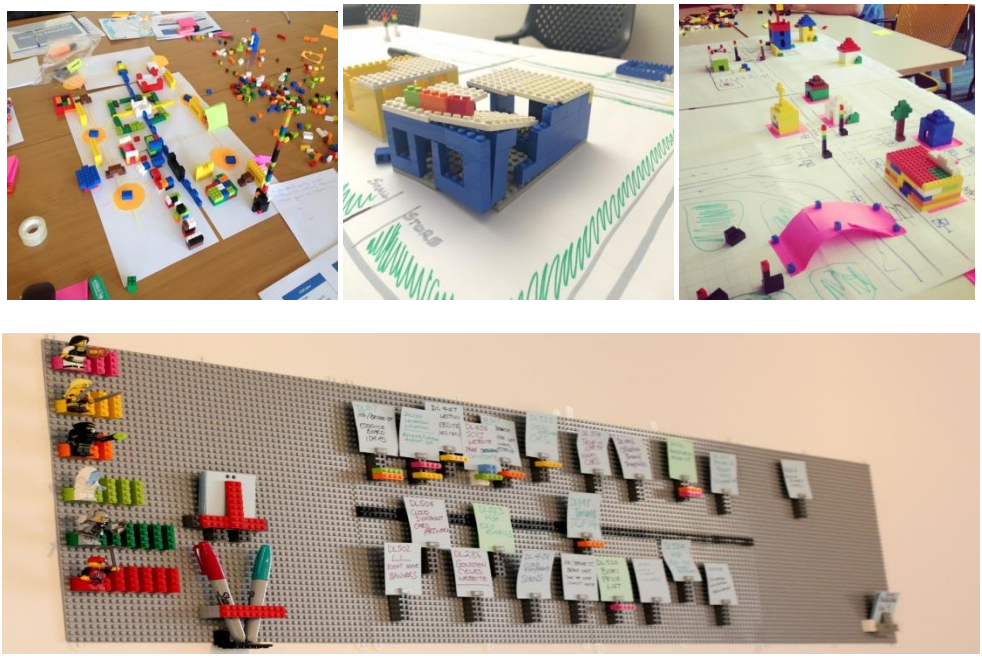

Figure 22. “Lego4SCRUM” serious game for introducing agile design processes.

When it comes to software and computer based applications that address teaching of lean and agile practices, once more, it is the “Beergame” but in its software version[xiv] which not only allows replicating the classic scenario but also manipulating various parameters of the game thus providing participants with ways to experience the differences between uncoordinated supply chains and those with information sharing and coordination. The “Beergame” facilitation software is a cross-platform client-server application that allows setting up ad-hoc beergame sessions in a classroom or workshop context. Once the instructor/game master starts a new event, students can simply log on to the server from their computers (either laptops, by using a wireless network, or from a lab computer). The only thing students need is a web browser with a flash plug-in. The front-end has been programmed in flash to provide an interactive game experience. During play, the instructor is able to see the progression of the beergame in real-time and more than one supply chain can be administered at the same time. As of August 2015, the “Beergame” software had already been distributed more than 600 times to institutions in over 60 countries

Figure 23. "Beer Game" videogame edition for introducing agile design processes.

Following the concept of facilitating training in agile methods, "Knowsy"[xv] is a simple game for tablets, which tests primarily how well the players know each other. One of the players picks a topic, and then secretly arranges, in order of his or her preference, the items presented. Other players then guess at the order in which he or she has arranged them. Knowsy has many applications, such as market research ("what do customers really want?") management offsite ("How well do managers understand company priorities?"), and corporate training ("who are the top competitors for our products?"). The game provides a springboard for further discussion ("Why do customers prefer one product over another?"), as well as to other games that build on the information that Knowsy can provide.

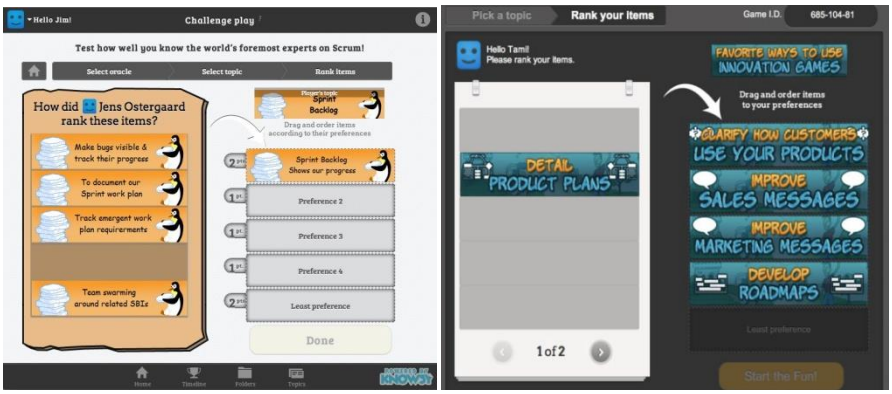

Figure 24. "Knowsy" application for introducing agile design processes.

13. LEAP PEDAGOGICAL METHODOLOGICAL DESIGN FRAMEWORK FOR PROMOTING INDUSTRIAL DESIGN PRACTICES IN HIGHER EDUCATION ACTIVITIES

The LEAP methodological learning framework aims to introduce a learning approach for building higher education skills related to agile and lean production design. The approach aims to enhance learning experiences for higher education students in relation to effectively deploying those skills in the context of projects related to industrial practices. The framework aims to expose learners to industry approaches that are well accepted for designing and implementing products and services that effectively meet end user needs. The proposed framework 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: problem based learning.

13.1 Fostering agile skills

The LEAP learning intervention is oriented to students of both universities and institutes. It is anticipated that these students can be familiarised with what the agile methodology is actually about. It is crucial to introduce students to the principles of the agile approach and afterwards to examine not only the advantages but also the disadvantages of this approach. The LEAP learning intervention targets novice students aiming to familiarize them with the key ideas of SCRUM agile processes and lean 5S design. The approach exposes students to these practices through a feedback-driven empirical approach encouraging them to engage with agile and lean process concepts, namely the commitment to accomplishing their goals, the courage to

make it work by overlooking liabilities, the understanding of investment towards managing technical debt, openness by being outspoken about their work and respect, meaning that their incentive should be benevolent. Furthermore, students will be able to differentiate the three roles that exist in a SCRUM team. More specifically, the product owner, the development team and the SCRUM Master.

Students are expected to perceive the fact that the product owner portrays the stakeholders. In addition, they should be capable of accepting the essential communication skill that a good product owner should have, so as to organize milestones reviews, educate stakeholders in the development process or even negotiate priorities, objectives, funding and schedule. Students will recognise that one of the most noteworthy finesse the product owner should have is to provide the essential information to the specific target group he/she interacts with. For instance, the product owner is obliged to know that the executive sponsor expects to be informed about the summary of the progress. The product owner should be insightful about providing information in terms of the feedback and the specifications of the product being developed to the development team. Providing further information would be meaningless and it may cause lack of interest, let alone the waste of time.

In relation to the role of the development team, students will be exposed to a virtual reality that will make them grasp how this kind of team functions. More specifically, students will be familiarized with the cross-functionality of this team and they will learn how to take part in a self-organizing team. At the end of the sprint, students will be obliged to deliver specific increments of a product. Last but not least, they will need to interact with a project management office.

Moving on the third important role in the SCRUM team, let’s introduce the SCRUM master. Students will face the challenge of absorbing this role. They will have to eliminate every single hindrance that comes up and holds

back the ability of delivering the product objectives successfully. This role also depicts a buffer that stands between the team and any other distracting influences. Students will get the main idea of being a SCRUM Master, since by enacting this role, they'll have to learn how to ensure that the proper framework is followed and the team follows the agreed processes. This way, students will learn how to respond to a virtual reality and they will be prepared to feel confident and experienced in case they have to face similar situations in their workplace. As a consequence, this serious game makes a connection between education and the real-case scenarios.

All of the three aforementioned roles foster creative thinking and decision thinking through role play that encourages critical and analytical mind sets.

Additionally, the students will be given the opportunity to learn about what the workflow and the artefacts of SCRUM are.

To start with the workflow, it is remarkable that a Sprint is the fundamental unit of development in SCRUM. This means that the Sprint is a time-boxed effort that has precise duration lying between one week and one month. Each Sprint starts with a Sprint Planning Event. This event aims to determine a "Sprint Backlog", thus recognise the tasks that have to be processed for the Sprint, and define the "Sprint goal". Each Sprint is completed with a "Sprint Review" and a "Sprint Retrospective". The last one reviews the progress being shown to the stakeholders and the work that needs to be done for the next Sprints. Students will be exposed Sprint processes in a manner that simulates real life. This way they are expected to visualise the way they'll be asked to determine the backlog of a project when they actually take part in it the future. Moreover, it provides them the opportunity to experience the preferred method to announce the progress of the project to the stakeholders.

This workflow includes the planning which is divided in two parts; in the first half, the SCRUM team is obliged to confirm the Product Backlog Items that have notable possibility of being achievable in that Sprint and in the second

half, the Development Team decomposes the whole project into the work items (tasks) that are required to fulfil those Product Backlog Items. Students that are going to use this serious game are anticipated to learn how to prioritize the feasible objectives that need to be completed in the specific Sprint and learn how to create small tasks that they will have to achieve in order to complete the objectives. Furthermore, they will get the main idea of how Product Backlog Items are created.

Moreover, the workflow contains the daily SCRUM, which is limited to fifteen minutes. During this SCRUM, students that are going to use this serious game are expected to spot any obstacles that may cause delay or problems in general. What is more, the student that enacts the SCRUM Master will end up in a resolution that extinguishes any hindrance. As a consequence, students will be trained to spot obstacles in the methodologies they are about to use in their real life and this is a key qualification in a real workplace.

Additionally, the “Review” and the “Retrospective” follows as parts of the workflow. At the Sprint Review (lasting about two hours for a two-week Sprint), the complete tasks are displayed to the stakeholders. Speaking of the uncompleted ones are reviewed by the team itself. In this part, the students are expected to understand how they should display the finished workload to the stakeholders and generally the process that takes place at this point.

At the “Sprint Retrospective”, (lasting one-and-a-half hours for a two-week Sprint), the whole process is about answering the two single questions. The first question is about what went well during this Sprint and the next one is about what could be improved in the next Sprint so as to make the whole procedure more effective. The SCRUM Master is the one that facilitates this event. Students learn to differentiate the tasks that were completed successfully from the tasks that weren’t accomplished. This way, they will per-

ceive the need of continually improving their methods in the real-case scenarios in order to scale up the effectiveness. Students learn by doing that they should keep on evolving in their career in case they want to be successful.

Another type of workflow, “Extensions” are some activities that are affiliated with SCRUM. Nevertheless, it’s highly conflicting whether they consist a core part of “SCRUM” or not. They are consisted of “Backlog refinement” and “SCRUM of SCRUMs”. To begin with, “Backlog refinement” is a continuous process in which the team keeps reviewing the Product Backlog Items and checking if it depicts the proper prioritization.

The whole point is about having articulate and executable Product Backlog Items that will be useful when the team enters Sprints via the Sprint Planning activity. Students here are expected to improve critical thinking by understanding whether the Backlog Items are substantive or other more useful ones should replace them.

Speaking of the “SCRUM of the SCRUMs”, this is a procedure in which scale SCRUM is applied to different teams that work for the same product. This process allows them to discuss their progress and concentrate on the coordination of the software delivery. Students learn in this process that their actions are interdependent on other teams’, so they will have to cooperate efficiently with other teams as well. These teams may be consisted of members that have different way of thinking or even working.

So in this exact procedure, students face the necessity of being receptive to what others may think or do. They should make an effort to communicate with others by setting aside the divergent of their opinions, if existed, and search for productive solutions. Moreover, all teams send their ambassadors to participate in the daily SCRUMs. Their ambassadors may be someone specialised in the specific context. Otherwise, they may be the “SCRUM Masters”. In their meeting they use a ROAM board in which they record the backlog so as to achieve better effectiveness. Students face steadily the

necessity of reassessing their workload and this assists them to understand the necessity of adaptability.

What's interesting about “SCRUM of SCRUMs” is the fact that every time when the ambassadors meet, in the “Daily SCRUM”, they have to answer four simple questions. The first one is about what hindrance, dependencies or even hypotheses they resulted in since the last time they met. The second one is about which of the above they will have to face in the near future. The third one is about whether there are obstacles that hold back the progress of the project and the fourth one is about introducing new setbacks that may cause significant delay to the other teams. Students are trained to be perceptive by recognizing which contents will cause impediments going forward and they should eliminate them.

In a nutshell, the students are expected to obtain specific knowledge about the agile skills and this will be very crucial for them, since they will have the opportunity to be trained in real-case scenarios. Finally, they will develop critical thinking, be exposed in a future workplace and this will make them grasp the idea that adaptability is a significant qualification that they will develop if they want to make a successful career. Adaptability in terms of the methodologies they will be about to use, the way they behave towards the other colleagues since the latest may have a different background that the students (users of the serious game) may have and the way they will have to detect the hindrance and improve them. This serious game fosters the openness to new ideas and approaches and this is exactly what makes the difference.

13.2 Problem-based Learning (PBL)

The serious game and methodologies that are developed in the context of LEAP project are defined by the principles of sound and widely accepted methodologies that ensure up to date and learner-oriented outcomes. The core philosophy around which is built LEAP, is Problem-Based Learning (PBL), an instructional method of hands-on, experiential and active learning

methodology that is centred on trial-error and investigation processes that lead to the resolution of complex real-world problems. Problem-based learning derives from the theory, initially described by Anderson (1977), according to which, “for effective acquisition of knowledge learners need to be stimulated to restructure information they already know within a realistic context, to gain new knowledge, and to then elaborate on the new information they have learned, for example by teaching it to peers or by discussing the material in a group setting”. PBL has been the one of the most important recent developments in Higher Education and it kicked off in the field of medical education in North America and has spread across the globe and across most disciplines.

Research (Barrows, 1986, Savery & Duffy, 1995, Kilroy, 2004) defines PBL as a pedagogical approach and curriculum design methodology that is often deployed with success in higher education and for various subjects and its definite characteristics are the following:

- Problems and use cases are context specific.
- Open-ended problems are those that drive Learning.
- There aren’t specific and unique “right” answers but only those that lead to solutions.
- Students are transformed in researchers and real problem-solvers that work in a self-directed and active mode.
- Students as problem-solvers work in small collaborative groups (typically of about five students) that identify the key problem and they agree upon a solution that is implemented until it proves to be efficient.
- Teachers have the role of facilitators of learning, guiding the learning process and encouraging inquiry.
- Critical thinking and creative skills are highly encouraged

In a PBL context, teachers don't merely provide facts or "transfer" knowledge and then test students' ability to memorize and recall facts but they encourage them to apply the newly "acquired" knowledge to a wide range of situations and make their way of thinking more abstract in its application. Most of the times, students are asked to investigate and resolve ill-structured problems by discovering and discussing about meaningful solutions with their peers. A learning procedure defined by the principles of PBL would follow specific consecutive and interrelated stages such as the ones below:

- First of all the class gets to know about a problem.
- Students discuss about it in the framework of a small group tutorial in order to specify and clarify the facts of the case.
- Later on they define what the problem is. Learners construct a shared primary model in order to explain the problem at hand while tutors and/or facilitators provide "scaffold".
- They brainstorm ideas based on the prior experiences and activate their prior knowledge through discussion.
- They construct a shared primary model to explain the problem at hand. Facilitators provide scaffold, which is a frame work on which students can construct knowledge relating to the problem
- They identify what kind of information is needed in order to work on the problem and this is when real knowledge emerges.
- They reason through the problem and after that they set up a coherent action plan towards the solution of the problem.
- Students might need to engage in independent study and individual research in order to tackle with their learning issues, which they identified in a previous stage. The information sources they draw on might include various resources such as the Internet, libraries, databases or even other people.

- They come back to the common field of work with their peers in order to share and exchange information as well as to collaborate on the given problem.
- Finally, they present and discuss their solution to the problem and they review what they have learnt from working on the problem.

Moreover, PBL addresses the need to promote lifelong learning through the process of inquiry and “construction of knowledge” since it is indeed considered a constructivist approach that is based on the emphasis on an equal combination of collaborative and self-directed learning that is supported by a tutor and facilitator or a “more experienced other” (Bodrova & Leong, 1996).

13.3 Constructivist learning

As previously mentioned, PBL is grounded in the constructivist perspective that transforms the instructor/teacher from a traditional “knowledge transmitter” to a facilitator who guides, inspires and challenges the learning process and students are considered to be active agents who engage in social knowledge construction. Any problem based learning activity boosts the creation of meaningful knowledge and personal interpretations of the surrounding world and its dynamics based on personal experiences and interactions. In other words, PBL guides the learner on the path from theory to practice during the whole problem solving process.

Constructivist learning upon which PBL is based, emerged as a prominent approach to teaching drawing from the work of Dewey, Montessori, Piaget, Bruner, and Vygotsky among others. Constructivism represents the ideal a shift from behaviourist educational models to education based on cognitive theory. Fosnot & Perry (1996) argues that Behaviourist epistemology focuses on domains of objectives, “pure intelligence”, reinforcement, various levels of knowledge, and clearly meaningless processes while Constructivist epistemology assumes that learners “construct” meaningful knowledge on the basis of social interaction with and within their environment.

The main pillars and epistemological assumptions of "constructivist learning" can be summarized in the following:

- Learners physically construct knowledge if and when they get involved in “hands-on”, active learning contexts.
- Learners build their knowledge in a symbolic way through their own representations of action;
- Knowledge is a socially constructed “product” that stems from interaction and the effort to (self – other) regulate knowledge.
- Knowledge is “invented” by learners when they seek for help from more experienced persons either these are tutors or peers, about concepts and processes they don't completely understand.

CONCLUSIONS

This report presented the LEAP methodological learning framework that aims contribute to the development of higher education student skills related to agile and lean industry production design. The framework is based heavily on Problem-Based approaches and active learning that is implemented through serious games. This combination aims to expose students to the way agile and lean processes are applied in practice. The framework is developed taking into account the actual needs of students and educators in the higher education sector in relation to building skills that are in-demand by the industry. This framework acts as the basis for the development of the LEAP learning game for building agile and lean skills, which corresponds to intellectual output 3 of the LEAP project.

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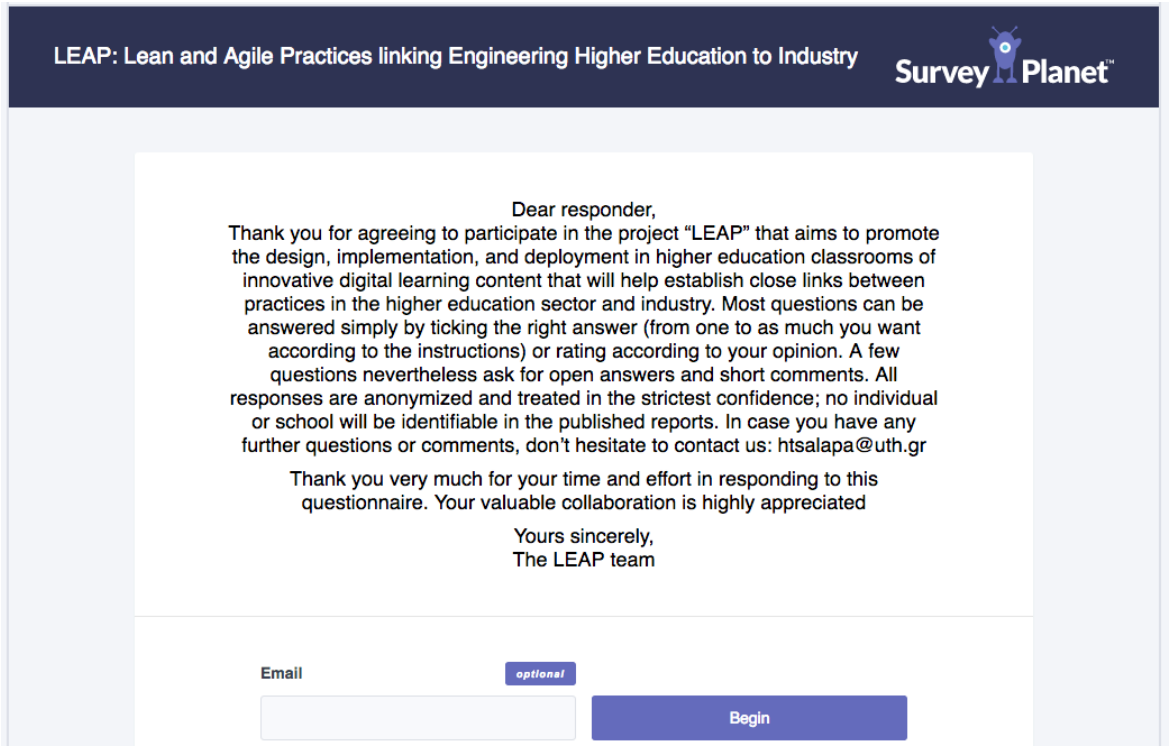
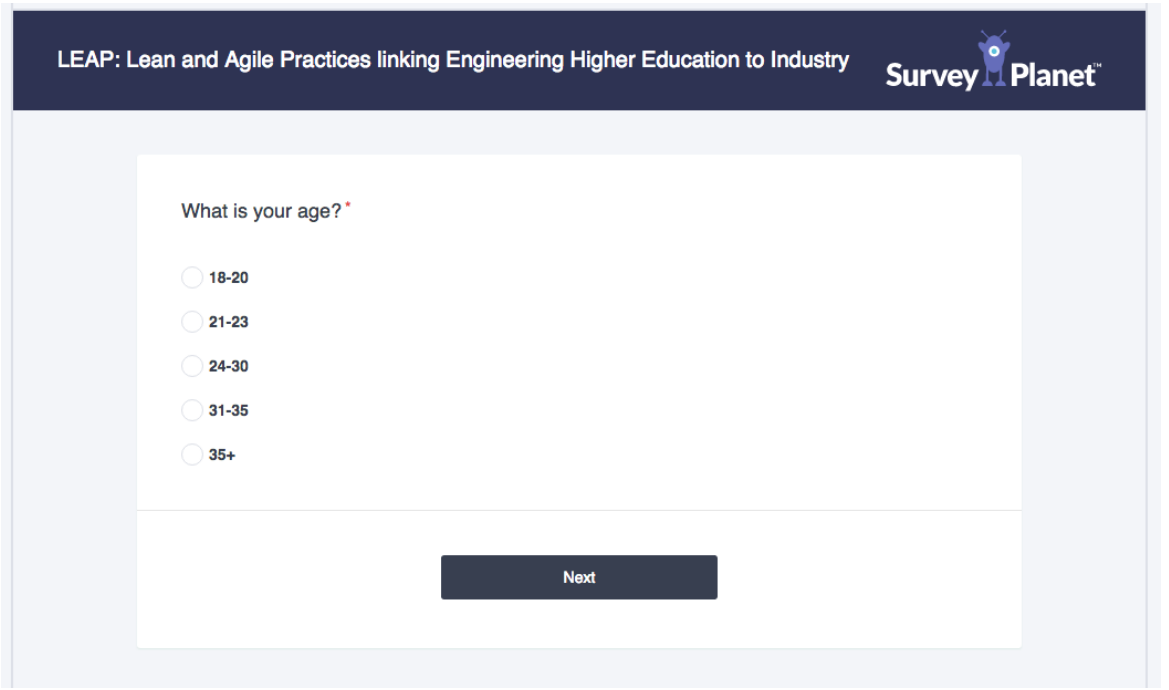
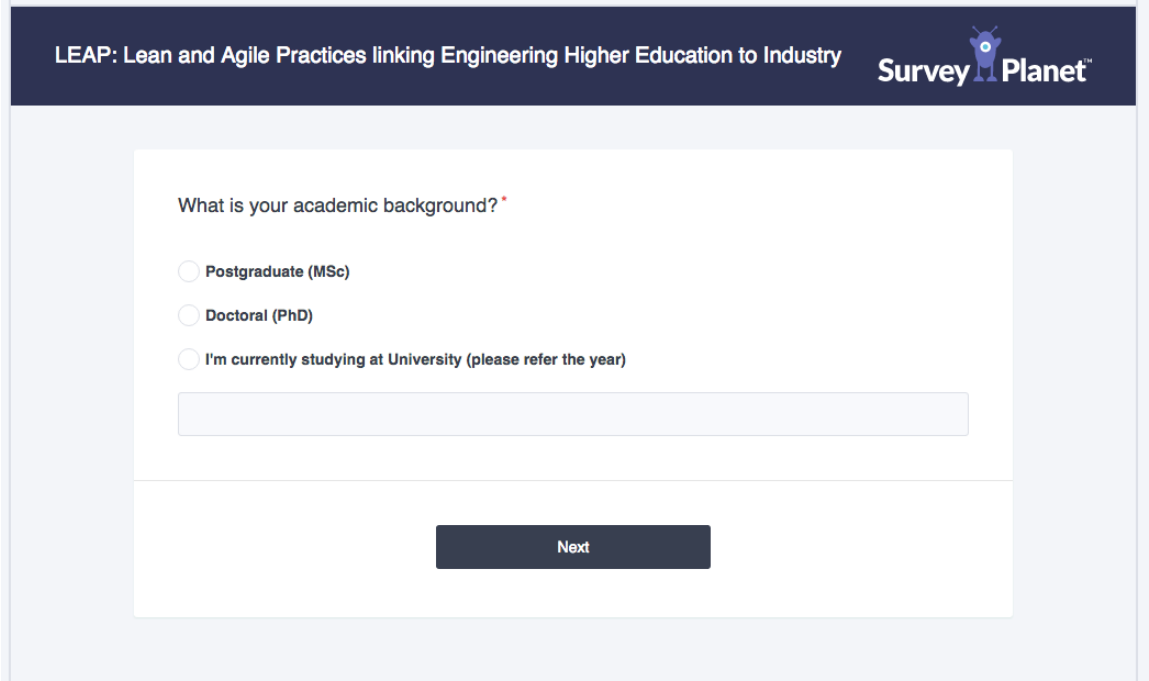
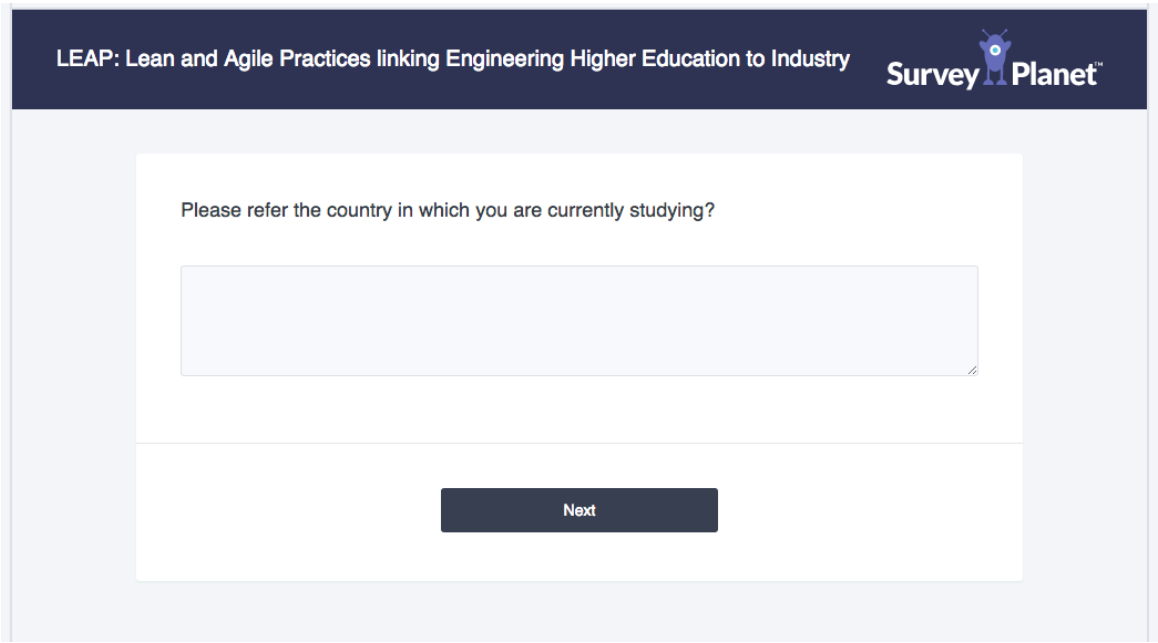
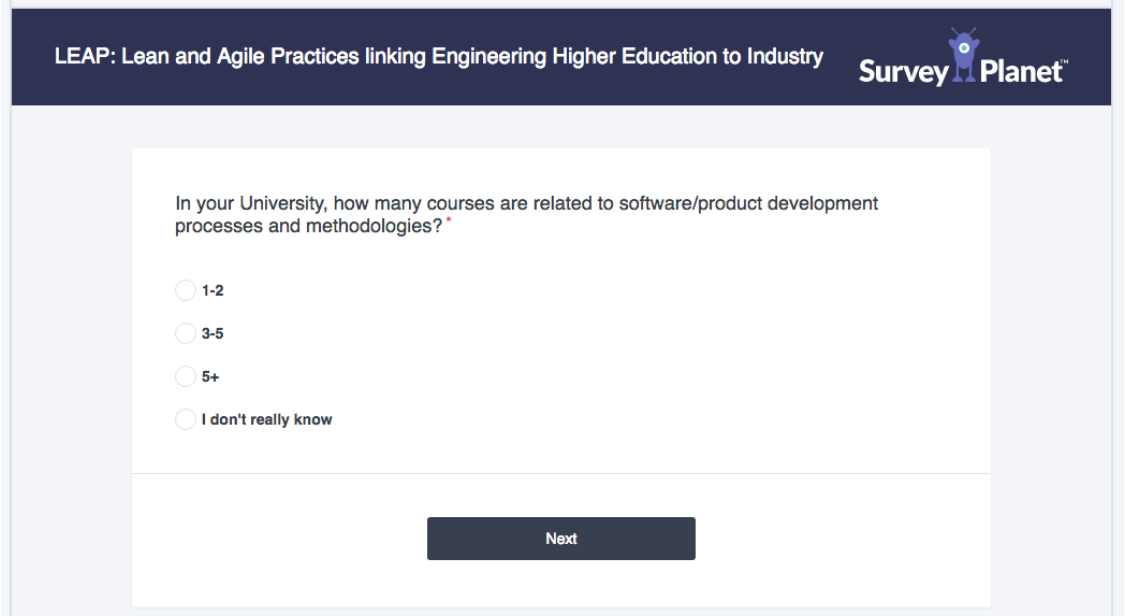
APPENDIX A: THE LEAP QUESTIONNAIRE

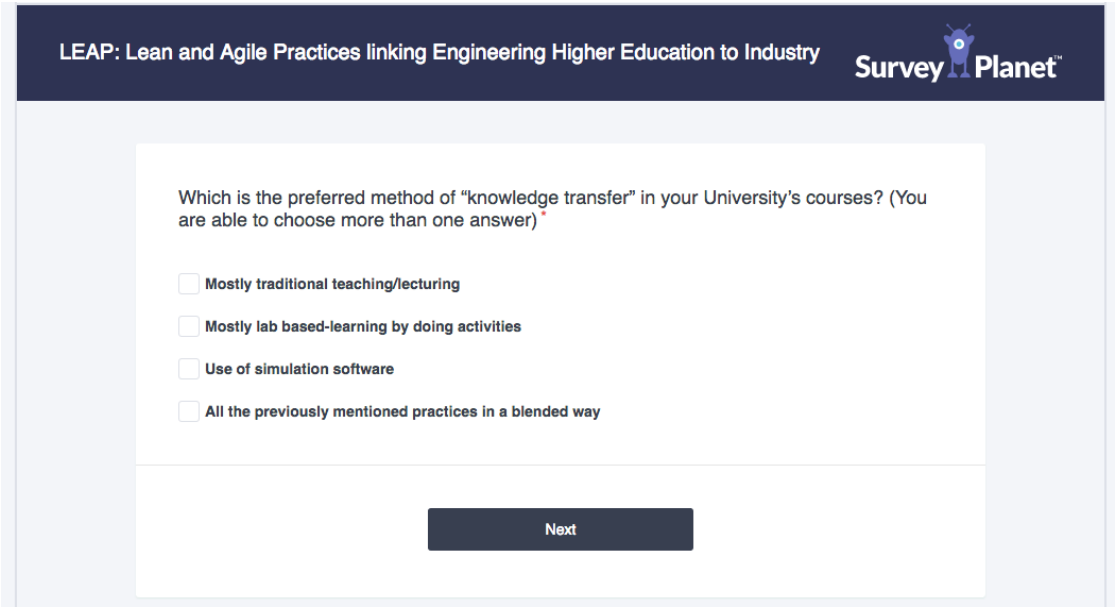


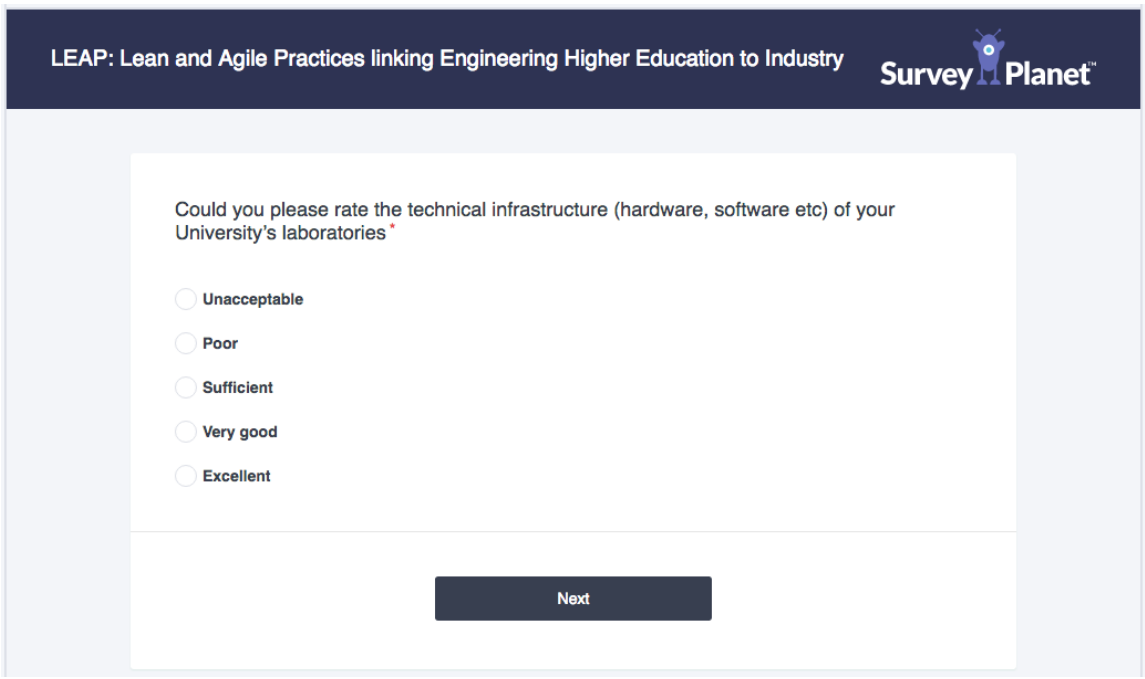


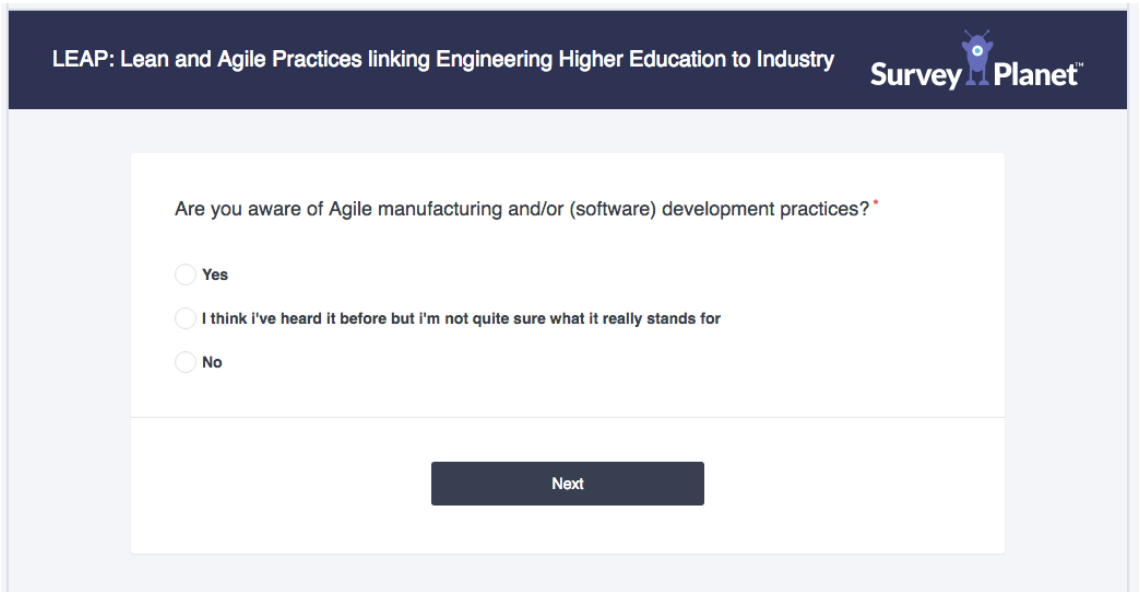

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
What is your academic background? *
Postgraduate (MSc)
Doctoral (PhD)
I'm currently studying at University (please refer the year)
Next

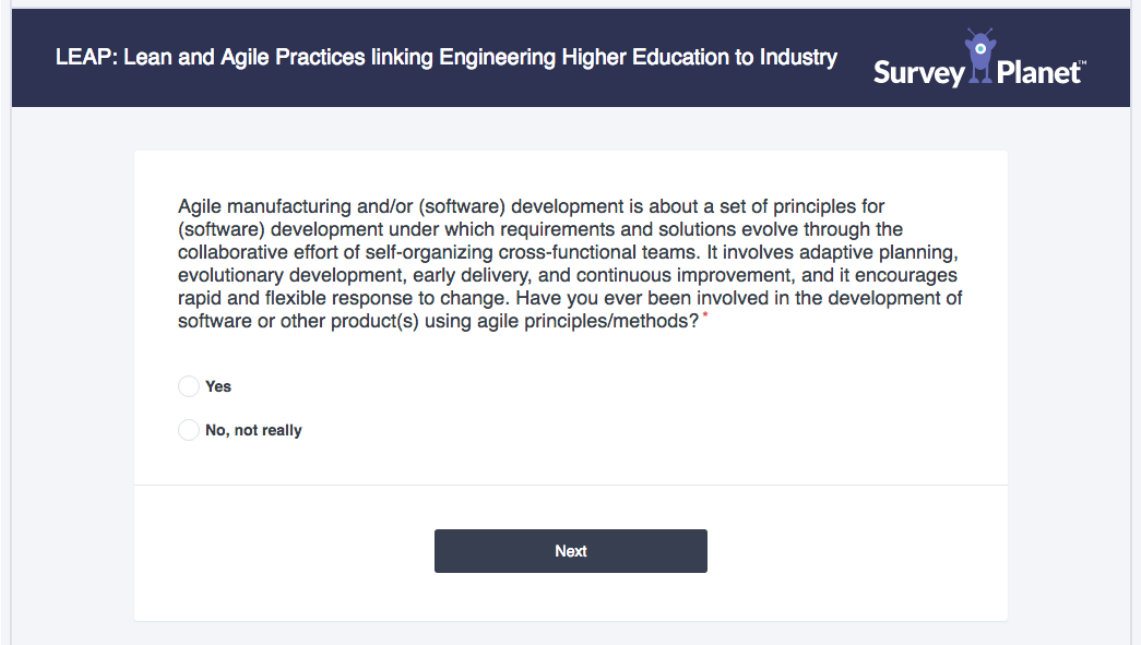

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Please refer the country in which you are currently studying?
Next

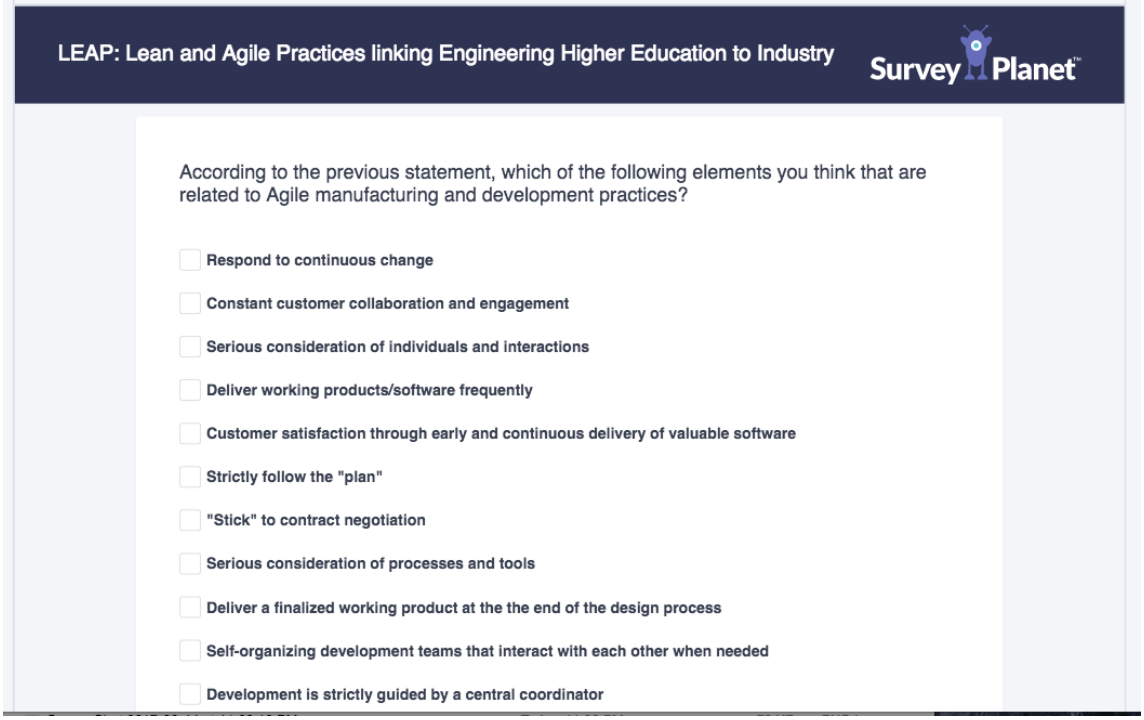

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
In your University, how many courses are related to software/product development processes and methodologies? *
1-2
3-5
5+
I don't really know
Next

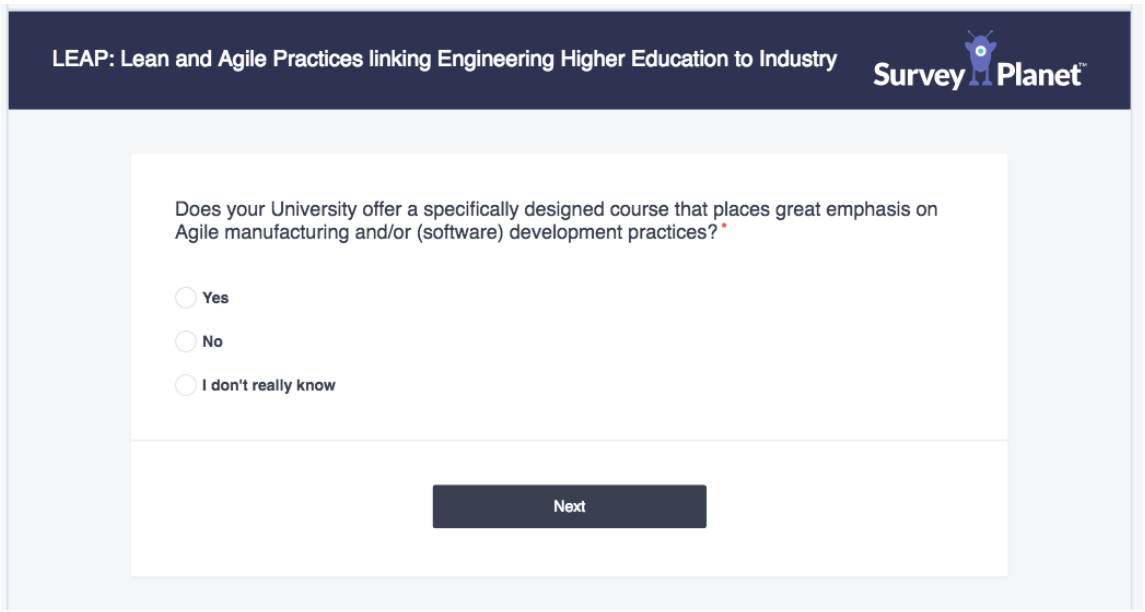

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Which is the preferred method of "knowledge transfer" in your University's courses? (You are able to choose more than one answer) *
Mostly traditional teaching/lecturing
Mostly lab based-learning by doing activities
Use of simulation software
All the previously mentioned practices in a blended way
Next

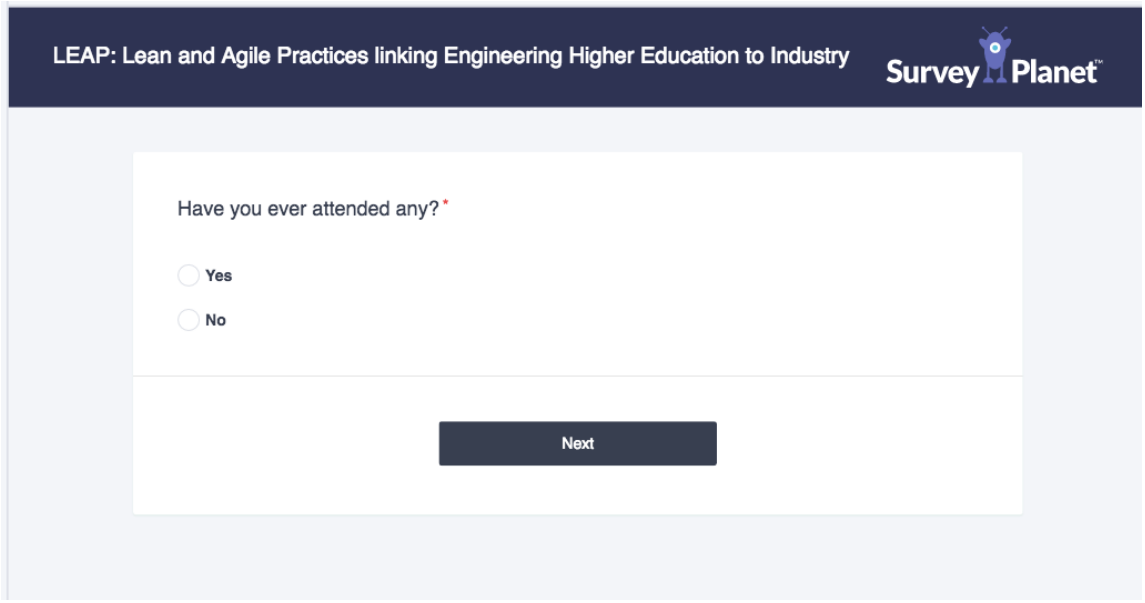

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Could you please rate the technical infrastructure (hardware, software etc) of your University's laboratories *
Unacceptable
Poor
Sufficient
Very good
Excellent
Next

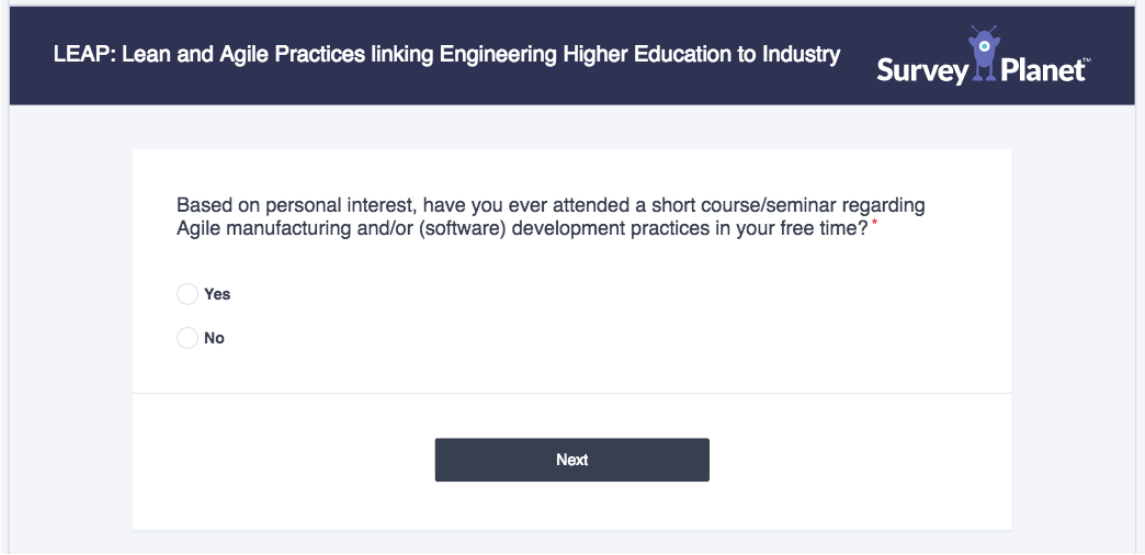

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Are you aware of Agile manufacturing and/or (software) development practices? *
Yes
I think i've heard it before but i'm not quite sure what it really stands for
No
Next

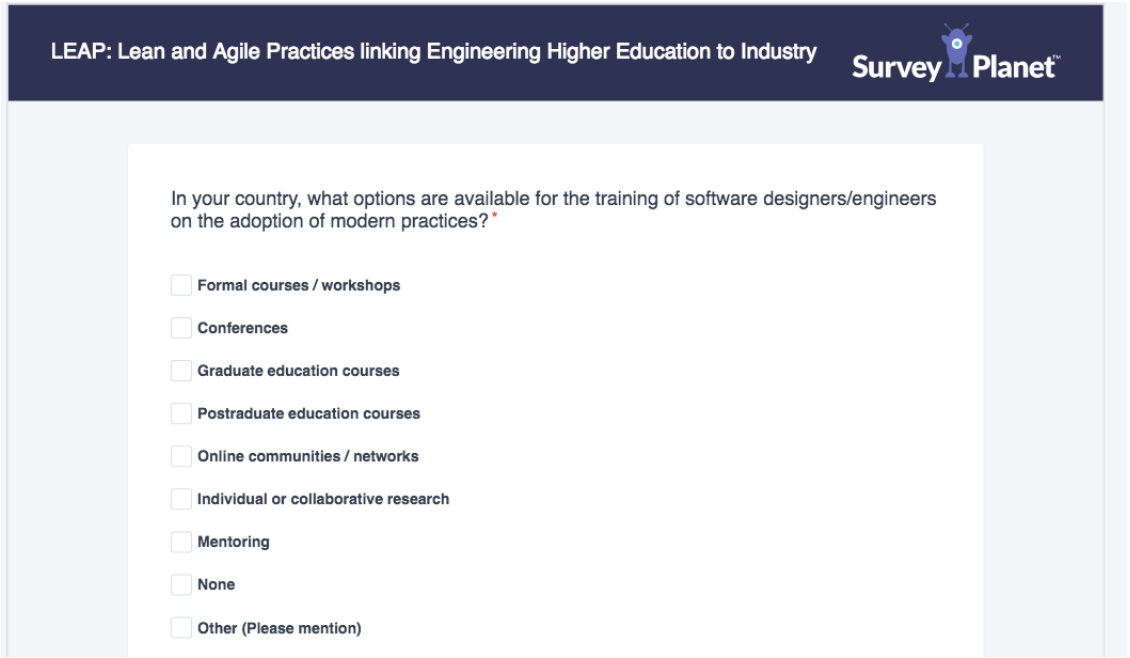

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Agile manufacturing and/or (software) development is about a set of principles for (software) development under which requirements and solutions evolve through the collaborative effort of self-organizing cross-functional teams. It involves adaptive planning, evolutionary development, early delivery, and continuous improvement, and it encourages rapid and flexible response to change. Have you ever been involved in the development of software or other product(s) using agile principles/methods? *
Yes
No, not really
Next

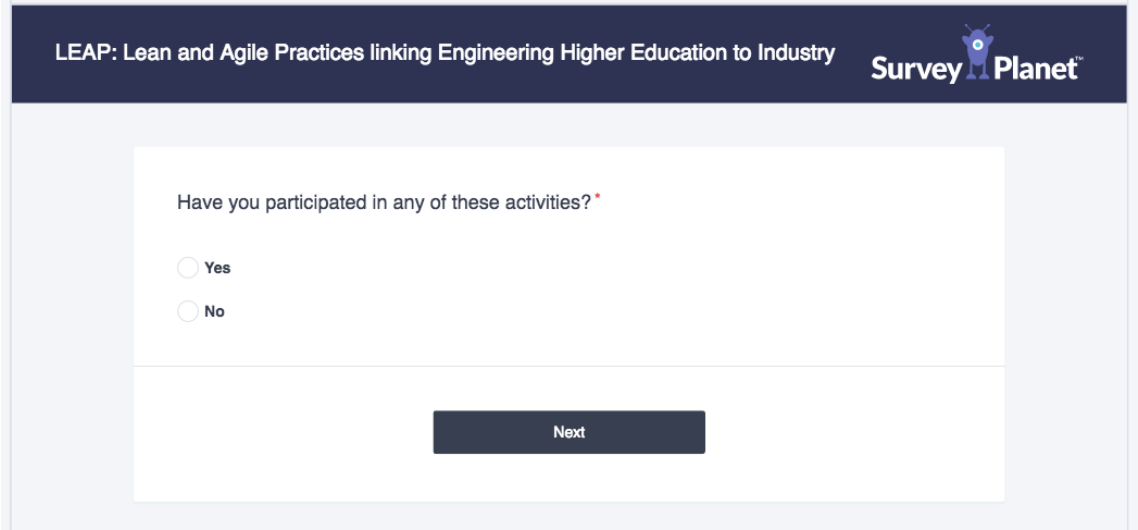

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
According to the previous statement, which of the following elements you think that are related to Agile manufacturing and development practices?
Respond to continuous change
Constant customer collaboration and engagement
Serious consideration of individuals and interactions
Deliver working products/software frequently
Customer satisfaction through early and continuous delivery of valuable software
Strictly follow the "plan"
"Stick" to contract negotiation
Serious consideration of processes and tools
Deliver a finalized working product at the the end of the design process
Self-organizing development teams that interact with each other when needed
Development is strictly guided by a central coordinator

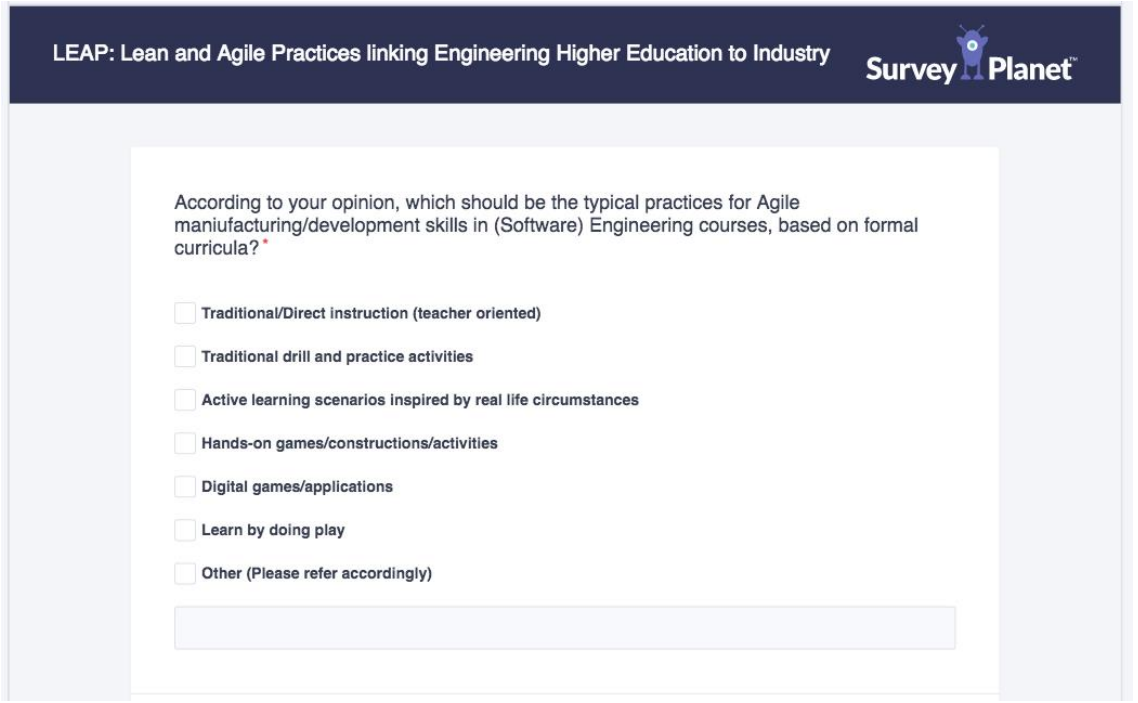

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Does your University offer a specifically designed course that places great emphasis on Agile manufacturing and/or (software) development practices? *
Yes
No
I don't really know
Next

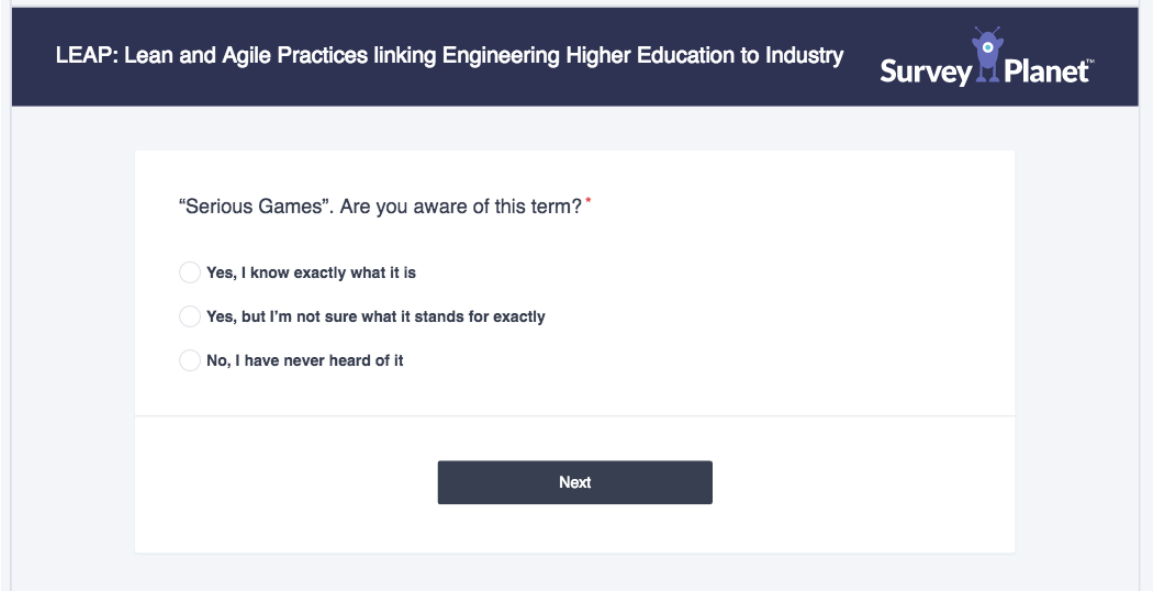

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Have you ever attended any? *
Yes
No
Next

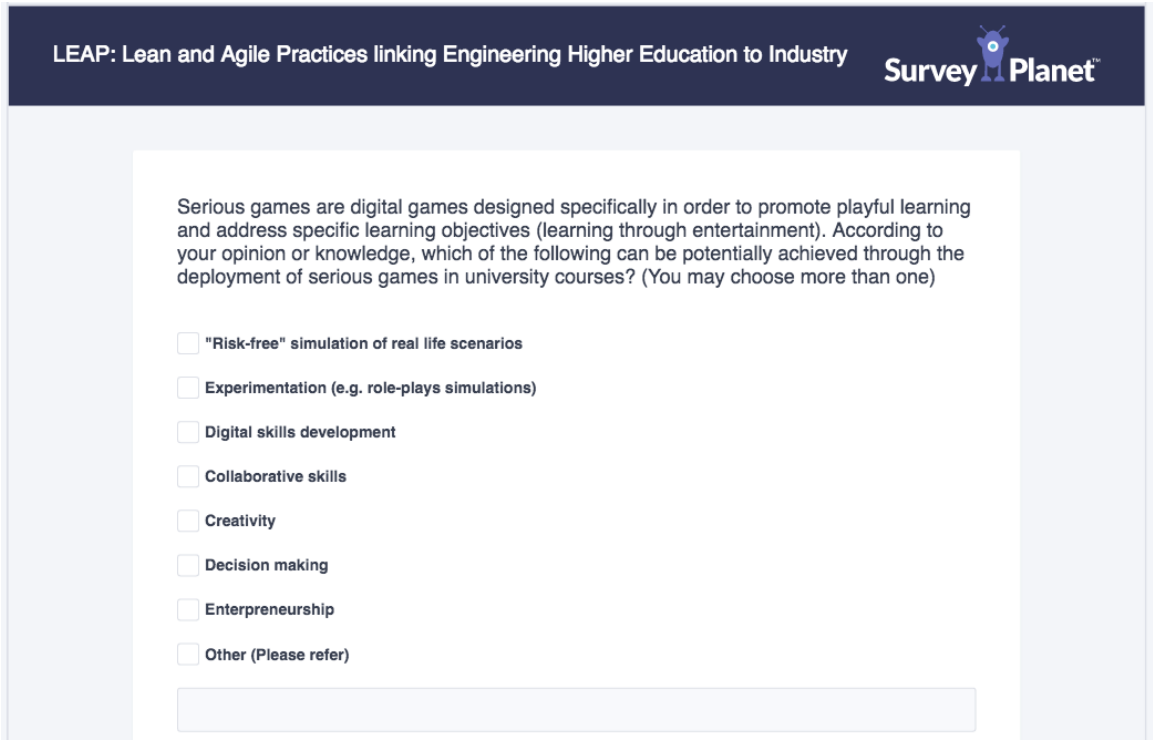

LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Based on personal interest, have you ever attended a short course/seminar regarding Agile manufacturing and/or (software) development practices in your free time? *
Yes
No
Next


LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
In your country, what options are available for the training of software designers/engineers on the adoption of modern practices? *
Formal courses / workshops
Conferences
Graduate education courses
Postraduate education courses
Online communities / networks
Individual or collaborative research
Mentoring
None
Other (Please mention)


LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Have you participated in any of these activities? *
Yes
No
Next


LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
According to your opinion, which should be the typical practices for Agile maniufacturing/development skills in (Software) Engineering courses, based on formal curricula? *
Traditional/Direct instruction (teacher oriented)
Traditional drill and practice activities
Active learning scenarios inspired by real life circumstances
Hands-on games/constructions/activities
Digital games/applications
Learn by doing play
Other (Please refer accordingly)


LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
"Serious Games". Are you aware of this term? *
Yes, I know exactly what it is
Yes, but I'm not sure what it stands for exactly
No, I have never heard of it
Next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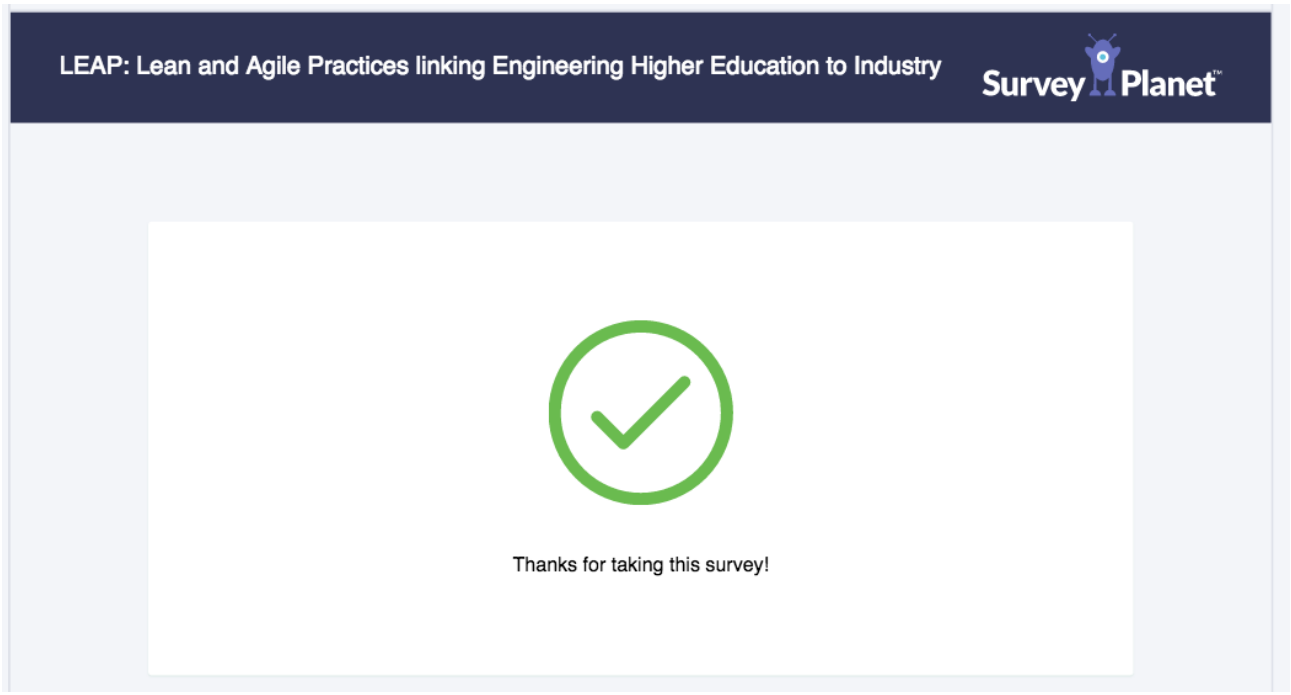
Survey Planet
Serious games are digital games designed specifically in order to promote playful learning and address specific learning objectives (learning through entertainment). According to your opinion or knowledge, which of the following can be potentially achieved through the deployment of serious games in university courses? (You may choose more than one)
"Risk-free" simulation of real life scenarios
Experimentation (e.g. role-plays simulations)
Digital skills development
Collaborative skills
Creativity
Decision making
Enterpreneurship
Other (Please refer)


LEAP: Lean and Agile Practices linking Engineering Higher Education to Industry
Survey Planet
Thanks for taking this survey!

APPENDIX B: AGILE PRACTICES TIMELINE

1968: “Conway’s Law”

“Conway’s Law” is coined and summarized as follows: “Any organization that designs a system (defined more broadly here than just information systems) will inevitably produce a design whose structure is a copy of the organization’s communication structure.” It has long had the status of folklore rather than of well-supported scientific result, though recent studies have lent it some academic support. (The social aspects of software development remained largely ignored by academic software engineering until the mid-90.)

1970s: Barry Boehm proposes “Wideband Delphi”, a forerunner of Planning Poker.

1976: A series of articles by D. Panzl describing tools with features closely resembling those of JUnit attest to the long history of automated unit testing.

1976: Publication of Software Reliability by Glenford Myers, which states as an “axiom” that “a developer should never test their own code” (Dark Ages of Developer Testing).

1977: Creation of the “make” tool for Unix systems - the principle of automating software builds is not a new idea.

1980: Substantial discussion of incremental development in IBM's Federal Systems Division can be found in a volume edited by Harlan Mills, "Principles of software engineering", specifically an article by Dyer, which recommends organizing "each increment to maximize the separation of its function(s) from function(s) in other increments"; however, the idea is still very much that of a scheduled, phased approach rather than one responsive to change.

1980: The notion of "visual control" originating in the Toyota Production System is an anticipation of "information radiators".

1983: A wide range of "human factors testing" techniques foreshadowing usability testing, used at the Xerox PARC during the design of the Xerox Star, are described in the CHI conference proceedings.

1984: An early empirical study by Barry Boehm of projects using prototyping, by essence an iterative strategy, suggests that iterative approaches first started receiving serious attention around that time, most probably driven by factors such as the rise of personal computers and graphical user interfaces.

1984: The notion of "factoring", an anticipation of refactoring, is described in Brodie's "Thinking Forth" [41], where it is presented as "organizing code into useful fragments" which "occurs during detailed design and implementation".

1984: While criticisms of the “waterfall” sequential approach have started much earlier, formulations of alternative incremental approaches are becoming more pointed; a good example is an early paper on ”Knowledge-based communication processes in software engineering” advocating incremental development for the specific reason that “complete and stable specifications are not available”.

1985: Perhaps the first explicitly named, incremental alternative to the “waterfall” approach is Tom Gilb’s Evolutionary Delivery Model, nicknamed “Evo”.

1986: In a well-known paper, Barry Boehm presents ”A Spiral model of software development and enhancement”, an iterative model geared to identifying and reducing risks through any appropriate approaches (though the “typical” example presented is based on prototyping).

1986: The term “SCRUM” appears in an article by Takeuchi and Nonaka ”The New New Product Development Game”, often cited as an inspiration for SCRUM, the framework; however, it only appears once (in the title of a section: “Moving the SCRUM downfield”) and does not at this point refer to any sort of meeting.

1988-1990: The rise of event-driven GUI software and their specific testing challenges create an opportunity for “capture and replay” test automation

tools provided by companies such as Segue or Mercury; this type of tool dominates the market for the next decade.

1988: The “timebox” is described as a cornerstone of Scott Schultz’s “Rapid Iterative Production Prototyping” approach in use at a Du Pont spin-off, Information Engineering Associates.

1988: Though the idea of reasoning through design issues by anthropomorphizing objects, as in the CRC technique, may seem quite natural, it has had some formidable detractors, for instance this artlce by Dijsktra ”On the cruelty of really teaching computing science”, which appears just as object-oriented is hitting the mainstream: “in computing science the anthropomorphic metaphor should be banned”.

1989: Ward Cunningham describes the CRC technique in a joint article with Kent Beck [43]; the specific format used for the cards derives from an application designed by Cunningham to store design documentation as a Hypercard stack.

1990: Bill Opdyke coins the term “refactoring” in an ACM SIGPLAN paper with Ralph Johnson, “Refactoring: An aid in designing application frameworks and evolving object-oriented systems”.

1990: Rebecca Wirfs-Brock describes the conceptual aspects of CRC, which she invented while she and Cunningham were working at Tektronix, in her book" Designing object-oriented software".

1990: Testing discipline dominated by "black box" techniques, in particular in the form of "capture and replay" testing tools.

1990's: Owing to the rise in popularity of RAD tools and IDEs, "make" type tools acquire a mixed reputation.

1991: James Martin in his "Rapid Application Development" describes RAD, possibly the first approach in which timeboxing and "iterations" in the looser sense of "one repetition of the entire software development process" are closely combined. This book also describes the details of the time box in one of its chapters.

1991: Independent creation of a testing framework at Taligent with striking similarities to SUnit (source).

1992: "Dynamic Duo" is the term coined by Larry Constantine, reporting on a visit to Whitesmiths Inc., a compiler vendor started by P.J. Plauger, one of the implementers of C: "At each terminal were two programmers! Of course, only one programmer was actually cutting code at each keyboard, but the others were peering over their shoulders." Whitesmiths existed from 1978 to 1988.

1992: A comprehensive description of “refactoring” is presented in Opdyke’s thesis, “Refactoring object-oriented frameworks”

1993: “The benefits of collaboration for student programmers” by Wilson et al. is one early empirical study indicating benefits of pairing for programming tasks specifically. Posterior studies are more abundant and driven by the desire to “validate” pair programming after it had already gained popularity through Extreme Programming.

1993: The phrase “continuous integration” is already in use and thus predates what will later be known as Agile processes, for instance an article written this year contrasts it with “scheduled” integration, and recommends the latter, citing “lack of thorough testing” as one issue with continuous integration; this helps explain why the automated testing favoured by Agile teams is an enabler for continuous integration.

1994: Jim Coplien, describing his observations of the “hyperprodutive” Borland Quattro Pro team, notes their reliance on almost daily meetings: “the project was made more of meetings than anything else”; this article is also cited as a strong influence on SCRUM.

1994: Kent Beck writes the SUnit testing framework for Smalltalk.

1995: Coplien names the “Code Ownership” pattern in Pattern Languages of Program Design, in an early version of his “Organizational Patterns”, a work influential in the later development of Agile discourse. However, he endorses exclusive individual code ownership, and cautions against collective ownership, which he equates to no ownership at all. Coplien admits that objections against individual ownership exist, but argues that other of his patterns mitigate those problems.

1995: An article by Alistair Cockburn, ”Growth of human factors in application development”, suggests one major reason why iterative approaches gradually gain acceptance: the bottleneck in software development is shifting to (individual and organizational) learning, and human learning is intrinsically an iterative, trial and error process.

1995: Based on the same inspiration as CRC cards, Ward Cunningham develops the concept of a Wiki, which will later become the ancestor of Wikipedia and undoubtedly one of the most influential ideas in the history of the World Wide Web.

1995: The earliest writings on SCRUM introduce the notion of the “sprint” as iteration, although its duration is variable.

1995: The pattern “Developing in Pairs” is given a brief description, in Alexandrian pattern form, in Jim Coplien’s chapter “A Generative Development-Process Pattern Language” from the first patterns book, “Pattern Languages of Program Design”.

1996: Steve McConnell describes the “Daily Build and Smoke Test” technique, used at Microsoft for Windows NT 3.0 during the 1990’s; the emphasis is not so much on the automation as on the frequency, the daily cycle being at that time considered “extreme”.

1996: Automated tests are a practice of Extreme Programming, without much emphasis on the distinction between unit and acceptance testing, and with no particular notation or tool recommended.

1997: Ken Schwaber describes the “daily SCRUM” (which does not appear in his earlier writings, such as the 1995 article “SCRUM Development Process”), this is later recast in pattern form by Mike Beedle.

1997: In ”Surviving Object-Oriented Projects”, Alistair Cockburn describes several projects (dating as far back as 1993) informally using the practice, but does not give it a label; he summarizes it as “Work in increments, focus after each”.

1997: The testing tool JUnit is written by Beck and Gamma, inspired by Beck’s earlier work on SUnit; its growing popularity over the next few years marks the end of the “capture and replay” era.

1998 to 2002: “Test First” is elaborated into “Test Driven”, in particular on the.

1998: Continuous integration and the "daily stand-up" are listed among the core practices of Extreme Programming.

1998: The earliest article about Extreme Programming, “Chrysler goes to Extremes”, describes several XP practices such as self-chosen tasks, test first, three week iterations, collective code ownership, and pair programming.

1999: Early on in the elaboration of Extreme Programming, the “System Metaphor” practice is proposed to address the issues of business-technical translation and cognitive friction, however the practice is poorly understood and fails to catch on.

1999: In an article for the C++ Report, Robert C. Martin gives what is perhaps the earliest description of the Agile sense of the terms “iterative” and “incremental”.

1999: Personas are first described in one chapter of Alan Cooper’s “The Inmates are Running the Asylum”, building on prior work in “Goal-Directed design”.

1999: The “rules of simple design” are described for the first time in an IEEE Computer article by Kent Beck, “Embracing Change with Extreme Programming”, summarizing earlier discussions on the OTUG mailing list.

1999: The practice of “refactoring”, incorporated a few years earlier into Extreme Programming, is popularized by Martin Fowler’s book of the same name.

1999: The term “Big Visible Chart” is coined by Kent Beck in “Extreme Programming Explained”, though later attributed by Beck to Martin Fowler.

1999: The unit “Gummi Bears”, an alternative to “story points” for estimating user stories, is first mentioned by Ron Jeffries (later attributed to an XP project led by Joseph Pelrine).

2000, ca: The “three questions” of SCRUM’s daily meeting format are largely adopted by Extreme Programming teams.

2000 (or earlier): The roles of Driver and Navigator are introduced to help explain pair programming; the earliest known reference is a mailing list posting; note however that the reality of these roles has been disputed, for instance Sallyann Bryant’s article ”Pair programming and the mysterious role of the navigator”.

2000: An article by Martin Fowler provides perhaps the most complete description of the continuous integration practice available at that time.

2000: The “mock objects” testing technique is described by Freeman, McKinnon and Craig in their article ”Endo-Testing: Unit Testing with Mock Objects”, an allusion to the “Mock Turtle” character in Lewis Carroll.

2000: The burndown chart is first described by Ken Schwaber, who invents it while working at Fidelity Investments in an attempt to provide SCRUM teams with a simple tool kit; he describes it formally on his Web site.

2000: The term “velocity” is a relatively late addition to Extreme Programming, replacing a previous notion of “load factor” deemed overly complex.

2000's: Even though the practice is far from new, nor limited to Agile teams, it is partly due to Agile practices that a revival of “make” type build automation takes place.

February 11-13 2001: 17 people who develop software and help others do it met at The Lodge at Snowbird ski resort in the Wasatch mountains of Utah to find common ground among their different approaches to software development. The outcome of this meeting is the Manifesto for Agile Software Development. Several members of that discussion went on to found the Agile Alliance.

2001: An avowed member of the “context-driven” school of software testing, Brian Marick participates in the Snowbird event leading to the publication of the Agile Manifesto; he has often described himself as the “token tester” of the group, bringing some awareness of practices within exploratory testing to the Agile community.

2001: Regular retrospectives are one of the principles of the Agile Manifesto: “At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly”, though not necessarily yet common practice.

2001: Mary Poppendieck’s article, ”Lean Programming”, draws attention to the structural parallels between Agile and the ideas known as Lean or the “Toyota Production System”.

2001: Cruise Control, the first “continuous integration server”, is published under an open source license; it automates monitoring of the source code repository, triggering the build and test process, notifications of the results to the developers, and archival of the test reports; the period 2001-2007 sees a large number of similar tools appear, leading perhaps to an excessive focus on tools over practice.

2001: Among the visualizations described in Norm Kerth's "Project Retrospectives", the "Energy Seismograph" can perhaps be seen as a forerunner of the niko-niko calendar.

2001: An article by Bill Wake points out two distinct flavors of estimation in use among Agile teams, relative and absolute estimation.

2001: Refactoring "crosses the Rubicon", an expression of Martin Fowler describing the wide availability of automated aids to refactoring in IDEs for the language Java.

2001: Some techniques of exploratory technique, together with a first mention of the "context driven school of software testing", are introduced in Kaner, Bach and Pettichord's "Lessons Learned in Software Testing".

2001: The "quick design session" is described in"Extreme Programming Installed".

2001: The "role-feature-reason" format for expressing user stories is invented at Connextra in the UK.

2001: The SCRUM of SCRUMs is first described (summarizing experiences at IDX) in an article by Jeff Sutherland, Agile Can Scale: Inventing and Reinventing SCRUM in Five Companies.

2001: The XP community endorses retrospectives early on, by way of a paper at XP2001 on ”Adaptation: XP Style”.

2001: The Card, Conversation, Confirmation model is proposed by Ron Jeffries to distinguish “social” user stories from “documentary” requirements practices such as use cases.

2001: The article which will later come to largely define project chartering as an agile practice is published: “Immunizing Against Predictable Project Failure”.

2001: The first description of a “reflection workshop” in the context of an Agile project appears in Alistair Cockburn’s ”Agile Software Development”.

2001: The term “Project Retrospectives” is introduced in Norm Kerth’s book of the same name.

2001: The term “information radiator” is coined by Alistair Cockburn, part of an extended metaphor which equates the movement of information with the dispersion of heat and gas.

2002: ”Pair Programming Illuminated”, by Laurie Williams and Robert Kessler, is the first book devoted exclusively to the practice and discusses its theory, practice and the various studies up to that date.

2002: Ward Cunningham, one of the inventors of Extreme Programming, publishes Fit, a tool for acceptance testing based on a tabular, Excel-like notation.

2002: An early article by Bill Wake calls attention to the possible inconsistencies arising from terms commonly used within teams, such as “done”.

2002: An early practitioner’s report discusses personas within the broader context: Jeff Patton’s “Hitting the Target: Adding Interaction Design to Agile Software Development” is perhaps the first formal description in an Agile context, although the topic has been discussed informally on mailing lists since at least 2000.

2002: In early (unpublished) discussions of applying Lean ideas to software, seeing the non deployed features as “inventory”, Kent Beck mentions continuous deployment at Life Ware and “several others”; it will take several years, however, for the idea to be refined and codified.

2002: The SCRUM community picks up the practice of measuring “velocity”.

2002: The burndown gains popularity among the SCRUM community, as well as alternatives such as the “burnup” which merely inverts the vertical direction, or the more sophisticated ”Cumulative Flow Diagram”, which most closely resembles a burnup but appears to be an independent invention.

2002: James Grenning sets out the current form of Planning Poker in an article.

2003: Joshua Kerievsky at Industrial Logic publishes ”Industrial XP”, a set of proposed extensions to Extreme Programming, which includes the Project Chartering activity, essentially as defined by the 2001 article.

2003: AgileDox, the ancestor of BDD, is a tool generating technical documentation automatically from JUnit tests, written by Chris Stevenson.

2003: Bob Martin combines Fit with Wikis (another invention of Cunningham's), creating FitNesse.

2003: Kent Beck briefly mentions ATDD in the book “Test Driven Development: By Example” but dismisses it as impractical. In spite of Beck's objections, ATDD becomes accepted practice due in part to the popularity of Fit/FitNesse.

2003 to 2006: The Fit/FitNesse combo eclipses most other tools and becomes the mainstream model for Agile acceptance testing.

2003: An anonymous article on the C2 Wiki describes Ping-Pong Programming [72], a moderately popular variant which marries pairing with test-driven development.

2003: Early SCRUM training materials hint at the future importance of the “Definition of Done”, initially only in the form of a slide title: “The story of Done”.

2003: Expanding on their earlier work on Lean Programming, Mary and Tom Poppendieck’s book ”Lean Software Development” describes the Agile task board as a “software kanban system”.

2003: Publication of "Test Driven Development: By Example" by Kent Beck.

2003: Thanks in good part to sessions at the XP Day cycle of conferences, more teams start practicing project and iteration retrospectives.

2003: The INVEST checklist for quickly evaluating user stories originates in an article by Bill Wake, which also repurposed the acronym SMART (Specific, Measurable, Achievable, Relevant, Time-boxed) for tasks resulting from the technical decomposition of user stories.

2003: The five-column task board format is described by Mike Cohn on his Web site; at the time, as this photo gallery collected by Bill Wake shows, very diverse variants still abound.

2003: The term “Nebulous Units of Time” or NUTs is coined by Joshua Kerievsky as an alternative to “story points”.

2003: The term “domain driven design” is coined by Eric Evans and described in a book of the same name, eventually emerging as a viable alternative to the “System Metaphor”.

2004 to 2006: The daily meeting is generalized as a core Agile practice, and with widespread use of task boards gains one final key guideline, “hold the daily meeting near the task board” (described for instance by Tobias Mayer).

2004: Kent Beck proposes “Whole Team” as the new denomination for the practice previously known as “On Site Customer”.

2004: An article by Alberto Savoia proposes “Extreme Feedback Devices” such as lava lamps or dedicated monitors, to display the results of the most recent integration, an important innovation in CI.

2004: In order to test his hypotheses about de-emphasizing “test” terminology in favor of “behavior”, Dan North releases JBehave.

2004: The INVEST acronym is among the techniques recommended in Mike Cohn’s ”User Stories applied”, which discusses it at length in Chapter 2.

2005: The Planning Poker technique is popularized in the SCRUM community, as are a number of planning techniques, by Mike Cohn’s “Agile Estimating and Planning”.

2005: The earliest recorded use of the term “backlog grooming” is from Mike Cohn on the SCRUM development mailing list; it will be several years before the practice is described more formally.

2005: The first exercises inviting SCRUM trainees to reflect on their (local) “definition of done” appear in later iterations of SCRUM training materials.

2005: Without giving it that name, Jeff Patton formulates the concepts of story mapping in “It’s All in How You Slice It”.

2006 to 2009: Several new tools are released confirming the community’s investment in BDD, such as RSpec or more recently, Cucumber and GivWenZen.

2006: Jean Tabaka’s book ”Collaboration Explained” references project chartering as one of the key practices for effective collaboration; though she explicitly cites Industrial XP her presentation differs in several respects from the 2001 article, indicating a synthesis influenced by other sources.

2006: In collaboration with Chris Matts, North proposes the given-when-then canvas to expand the scope of BDD to business analysis and documents the approach in “Introducing BDD”.

2006: Niko-niko calendars are first described by Akinori Sakata in this article.

2006: The first conference article describing the core of continuous deployment, ”The Deployment Production Line” by Jez Humble, Chris Read and Dan North is published in the proceedings of Agile2006, a codification of the practices of several Thoughtworks UK teams.

2006: The publication of Esther Derby and Diana Larsen's "Agile Retrospectives" brings to a close the codification of heartbeat retrospectives.

2007: By that point the "Definition of Done" as a full-fledged practice, and as a textual checklist displayed in the team room, has become widespread.

2007: The "kanbandev" mailing list is formed to provide a venue for discussion of kanban-inspired Agile planning practices.

2007: The first few experience reports from teams using the specific set of alterations known as "kanban" (no iterations, no estimates, continuous task boards with WIP limits) are published, including reports from Corbis (David Anderson) and BueTech (Arlo Belshee).

2007: The simplified three-column task board format ("To Do", "In Progress", "Done") becomes, around that time, more popular and more standard than the original five-column version.

2008: Alan Cooper's keynote at Agile 2008 marked a formal reconciliation, of sorts, between Agile discourse and interaction design, which had long been perceived to be at odds; invited by "the Agile leadership" as an "outsider", Cooper came to be perceived over the following year as very much an "insider".

2008: An emerging definition of exploratory testing is given by Cem Kaner, reflecting the continuing refinement of this approach to testing.

2008: One of the first formal descriptions of “backlog grooming” is given by Kane Mar, under the name “Story Time”, and recommending it as a regular meeting.

2008: The Agile 2008 conference features a stage dedicated to discussion of “User Experience” practices, such as usability testing, personas or paper prototyping.

2008: The story mapping practice is described and abundantly illustrated in Jeff Patton’s “The new user story backlog is a map”.

2008: While the first few allusions to teams using a “definition of ready” date to the beginning of that year, the first formal description seems to be from October, and is incorporated into “official” SCRUM training material shortly thereafter.

2009: The practice of continuous deployment has become well established, though still somewhat controversial as a much commented upon article, ”Continuous Deployment at IMVU” by Timothy Fitz attests [85]; it has become important not only in Agile but also as a core element of more specialized, recent strategies such as Lean Startup or DevOps.

2009: Two entities dedicated to exploring the kanban approach are formed, one addressing business concerns, the LSSC and a more informal one aimed at giving the community more visibility: the Limited WIP Society.

2010: A comprehensive description of integrating mock objects, TDD and OO design is provided in Freeman and Pryce's ”Growing Object-Oriented Software Guided by Tests” .

2011: The practice of “backlog grooming” is promoted to an “official” element of SCRUM with its inclusion in the SCRUM Guide.

LINKS

[i] https://crowdfavorite.com/agile-design-what-weve-learned/

[ii] http://www.agiledata.org/essays/evolutionaryDevelopment.html

[iii] http://www.ambysoft.com/surveys/success2007.html

[iv] http://www.ambysoft.com/surveys/agileFebruary2008.html

[v] http://kasvustrateegia.mkm.ee/index_eng.html

[vi] http://plase.csd.auth.gr/

[vii] https://qa.auth.gr/el/class/1/600039745

[viii] http://www.tjo.ee/?id=11007#6

[ix] http://www.leanway.ee/lean-meetodid-ja-terminid/

[x] http://www.addenda.ee/sisekoolitus-kulusaastlik-juhtimine--lean-juhtimine

[xi] http://www.agile42.com/en/training/kanban-pizza-game/

[xii] http://www.agile42.com/en/training/SCRUM-lego-city/

[xiii] https://en.wikipedia.org/wiki/Lego_Serious_Play

[xiv] http://www.beergame.org/software

[xv] http://www.SCRUMknowsy.com/