ICT-INOV
MODERNIZING ICT EDUCATION FOR HARVESTING INNOVATION

# D2.1 Methodological learning framework

618768-EPP-1-2020-1-EL-EPPKA2-CBHE-JP

| Document Info | |
|---|---|
| **Project reference** | **618768/2020** |
| **Deliverable** | D2.1 Methodological learning framework |
| **Dissemination level** | Public |
| **Date** | 31/1/2023 |
| **Document version** | 2.1 |
| **Status** | Final |
| **Sharing** | CC-BY-NC-ND |
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## Content



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# 1. Introduction

Project ICT-INOV aims to enrich the innovation skills among computer engineering and science higher education students and to prepare them for their role as problem-solvers in their professional careers. This report analysis the proposed methodological learning framework, which deploys design thinking and gamification principles enriched through digital learning services.

Design thinking provides a means for introducing ideas to complex problems even when none appears to exist at first sight. This is achieved through a stepwise process of empathy, problem-statement definition, brainstorming, prototyping and evaluation. The process allows a better understanding of the actual problem. It further enables a more effective analysis of user needs and desires by encouraging designers to put themselves in the user's position and experience the challenges that users face.

Gamification is a process that deploys game elements in non-game contexts, such as learning. Gamification elements have a broad range and may include a sense of affiliation, clear missions, recognition, awards, penalties, collaboration and more. Gamification encourages the long-term engagement of students in learning.

Finally, digital technologies, when integrated with innovative learning desing, enrich classroom experiences through higher interaction, collaboration and direct feedback further promoting the collaboration and problem-solving capacity of students.

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This report summarises the results of task T2.1 related to the survey conducted among students and educators from the proposed design thinking and gamified educational framework for fostering innovation in computer science education and of task T2.2 on the design of the proposed design thinking and gamification based educational framework.

In particular, the document reports the results of a survey that was conduceted through the engagement of students towards establishing expectations for building innovation skills, learning needs analysis and methodical learning framework based on experiential approaches integrating design thinking and gamification elements.

The second part of the document presents the ICT-INOV methodological framework that is based on the design thinking approach and gamification techniques taking into account the results of the student expectations survey.

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# 2. Student survey framework

The survey among students was conducted through a questionnaire that included 23 opena nd closed questions. It is available in *Annex 1 – Student survey* questionnaire. The areas investigated are three: the students' profile to collect general information about the respondents; the attitude and ideas of students about the innovation in terms of meaning, skills and their relevance in both education and ICT sectors; the learning and teaching approaches currently applied for the innovation skills building in each HEI involved in the survey.

The questionnaire was submitted through an on-line Google form to reach a higher number of students in Greece, Estonia, Portugal, Italy, Malaysia, Nepal, Pakistan and Vietnam in March 2021.

## 2.1 The student profile

The student sample consisted of 368 respondents (61,1% male and 39,1% female) in the countries mentioned above, including a small percentage of international students (7,61%). The student sample distribution is presented in the following figure.

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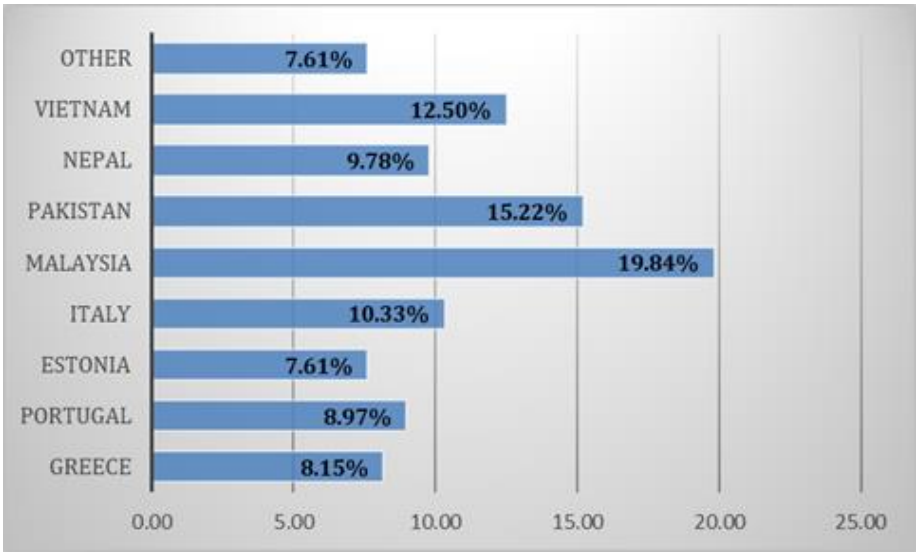


**Figure 1. Students' sample distribution among the countries involved**

The results show that most of the students are aged 18 - 25 years (73,1%) while less were aged between 26 – 30 (16%) and or than 30 years (11,4%). Their level of study falls into three types of academic study: Bachelor (65,5%), Master's (28%) and PhD (only 7,6%). The areas of study for participants are mainly ICT (51,26%), Engineering (36,97%), Social studies (6,16%), Business (3,64%) and Science (1,96%), as shown in the following figure (see more in *Annex 2 – Content analysis*).

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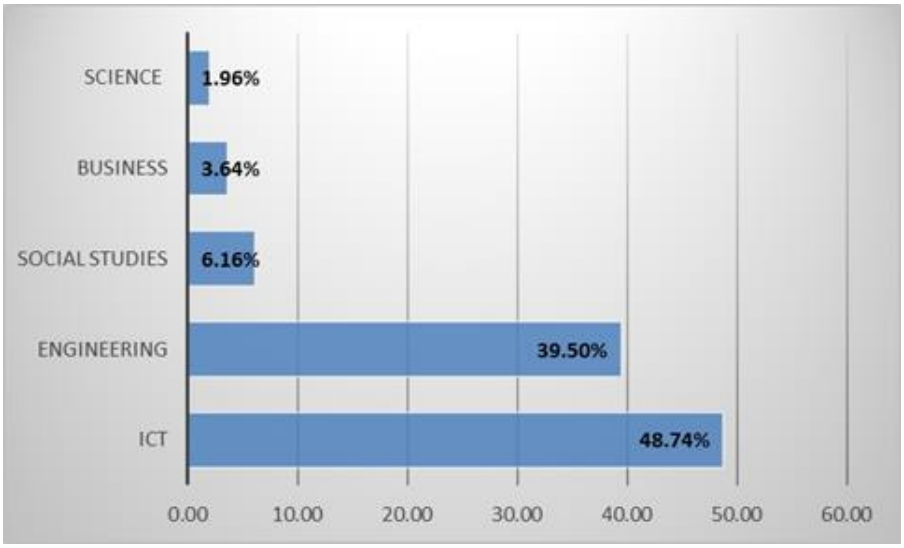


**Figure 2. Students' sample distribution among the countries involved**

*Results on 357 relevant answers*

Regarding the year of study, most students were "in the middle of their academic study" (39,4%), some were "about to finish" (34,2%) and others were freshmen (28,5%). The percentage calculations were exectured on the number of "relevant answers" namely 357 units of the sample.

## 2.2 Student attitudes towards innovation

There are many definitions of "innovation". Primarily the concept was borrowed from the business sector. However, today it is also used in other sectors, for example popular press, business publications and research literature. The last has contributed and still contributes to the general confusion regarding the concept of "innovation". The result is that everyone has their own understanding of the concept [1].

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For this reason, six definitions of "innovation" were provided in the questionnaire for students to select from for describing their understanding of the concept. This question is important for helping the consortium understand students' perceptions on "innovation".

The following definitions were provided as possible selections on the meaning of the concept of "innovation":

1. "…the successful conversion of new concepts and knowledge into new products services or process" from *American Society for Quality* - ASQ [2] [3].
2. "Innovation is significant positive change" (Scott Berkun)[4].
3. "…is the creation and capture of new value in new ways." (LeAnna J. Carey – co-founder of *Women Who Innovate* - a forum for women innovators) [1].
4. "Innovation is change that creates a new dimension of performance." (Peter Drucker)[5].
5. "Innovation transforms the useful seeds of invention into widely adopted solutions valued above every existing solution" (Braden Kelley)[6].
6. "Making connections to bring something new to the world." (Bill O'Connor - founder of *The Innovation Agency*)[7].

Most students (30,4%) agree with the statement of "innovation" made by the *American Society for Quality*, that is "…the successful conversion of new concepts and knowledge into new products, services or process" as shown in the following figure.

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**Figure 3. Students' sample distribution according to their opinion about innovation**

*Results on 368 relevant responses*

In addition, an open question was added to gather other relevant qualitative information on student opinions and gain valuable input that cannot be revealed from a strict definition and a closed question.

Based on the responses to the open question, some respondents agree that "innovation" is not restricted to one definition. Rather, all definitions provided as alternatives in the questionnaire make sense because each reveals a single or several of its distinctive aspects.

Some students wrote the following sentences about their understanding of "innovation":

- Innovation is converting an idea into a new product. For example, the idea of solar energy gen into solar panels.
- All suggested definitions are relevant; innovation refers to idea implementation on a current product or service or towards the creation of a new one.

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- Innovation is a spark; it's a beam of light that illuminates an old method or creates a new one by mixing existing ones.
- All suggested definitions make sense.
- Innovation has value in commercialization or improvization.
- Innovation refers to something new derived from previous knowledge. It mostly referes to applicable items but is also relevant in newfound theories.
- Innovation is something that an individual engages in not for themselves but for yourself but people all over the world.
- Innovation is proposing a new perspective, regardless of its success, in an already existing industry.
- Innovation is the conversion of an old idea into new and better ideas.
- Almost all suggested definitions are relevant.
- Innovation is a change in existing knowledge and practices, adopting new techniques, changing existing ways of working, often using new technologies. Its purpose is to bring positive change, but it doesn't always work out that way. Each positive change can have its dark side. Innovation can also lead to alienation as old, less efficient methods sometimes have positive upsides. At the same time, innovation can eliminate some ineffective old practices that are bringing everybody down.

Based on the above input, all respondents agree that “innovation” is constantly transforming a current situation into something new. Students perceive that it is not important if the new state


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resulting from innovation ever existed before in a different form, is the result of a unique new process or combination of existing elements. Innovation integrates elements of all definitions to a greater or lesser degree.

Some students stated that they are currently engaged in activities for building innovation skills (30,7%). However, the majority (70,7%) reported that they have not yet engaged in related activities. For those students that responded that they have engaged in innovation skill development activities, the following were some of the learning practices reported that they have participated in:

1. **New product realisation**. Students engaged in activities targeting the production of an innovative product or service to improve currently available solutions.
2. **Implementation of new solutions**. Students engaged in activities related to the design of new solutions for improving or enriching existing ones.
3. **Participation in events, seminars or wider contexts focused on innovation**. Students underlined the importance to participate in events, seminars or other activities focused on innovation regarding different sectors for improving their design skills.
4. **Learning new skills**. Students engaged in activities aiming at capacity building in their selected field of study for reinforcing and developing innovation skills.
5. **Innovative teaching methodology applications**. These activities focused on applying emerging teaching methods in courses that aim to develop innovation skills.
6. **Involvement in innovative processes**. Activities are focused on the introduction of new ideas or projects.

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According to Diya Moubdi et al.[8], the reinforcement of key competencies can support specific innovative, long-term strategy in all sectors and particularly in business. Skill and competency development is a challenge that can drive the design and innovation in education for preparing students to cope with the new world [9].

The competency framework proposed by this research helped identify some a list of desirable skills for innovation [8] such as analytical thinking, data gathering and analysis, generalisation and abstraction, problem-solving, reasoning, creative thinking, out-of-the-box thinking, collaboration capacity, investigating sources, being imaginative, evaluation of ideas stemming from different sources, communication skills and time management. To document student perceptions on desirable skills related innovation, students were encouraged to select 3 – 5 skills from this list as shown in the following figure.

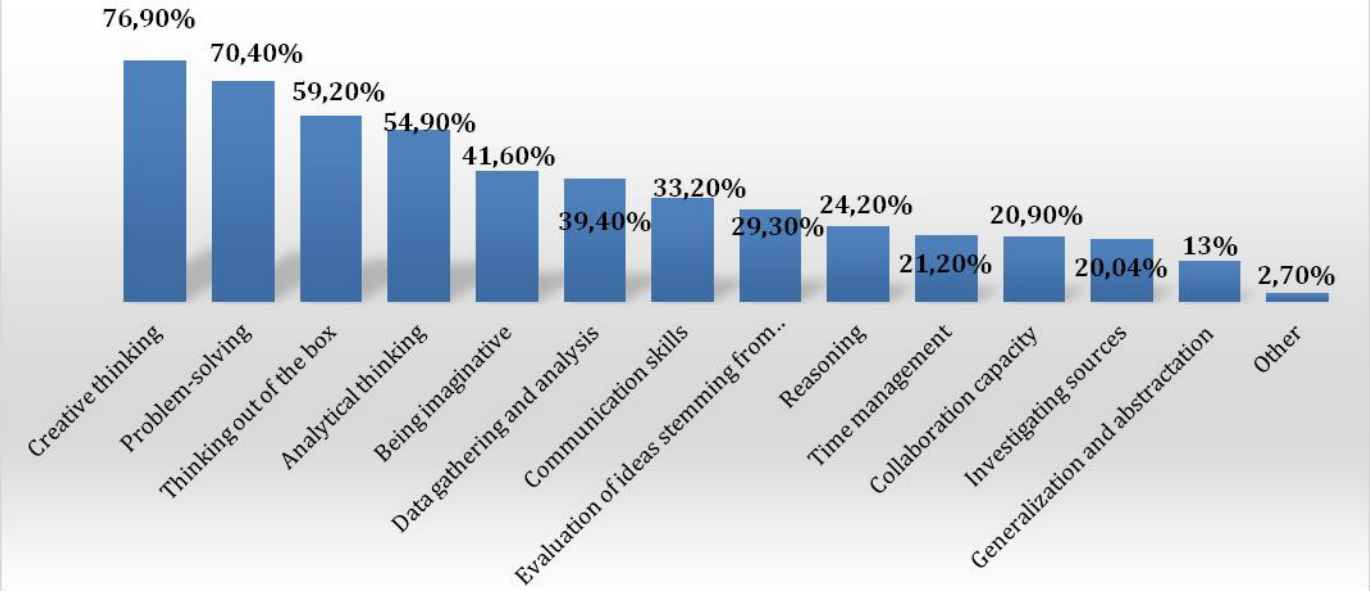


**Figure 4. The essential skills for innovation in education recognised by the students**

*Results on 368 relevant responses involving 3 - 5 selections from the list of suggested innovation skills*

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The top-ranked student selections related to essential innovation skills are the following: creative thinking (76,90%), problem-solving (70,40%), thinking out of the box (59,20%) and analytical thinking (54,90%).

In relation to the importance of innovation skills in ICT education, the majority of respondents consider these skills as very important (49,7%) or important (and 41%). However, a small percentage (8,4%) had a neutral attitude towards innovation skills.

Student perceptions are a little different in relation to innovation skills necessary for ICT careers. Most students consider innovation skills to be very important (46,2%) or important (44,8%). At a closer look, when considering the particular skills, most students consider problem-solving as important (71,20%), followed by creative thinking (62,80%) and analytical thinking (54,90%) as demonstrated in the following figure.

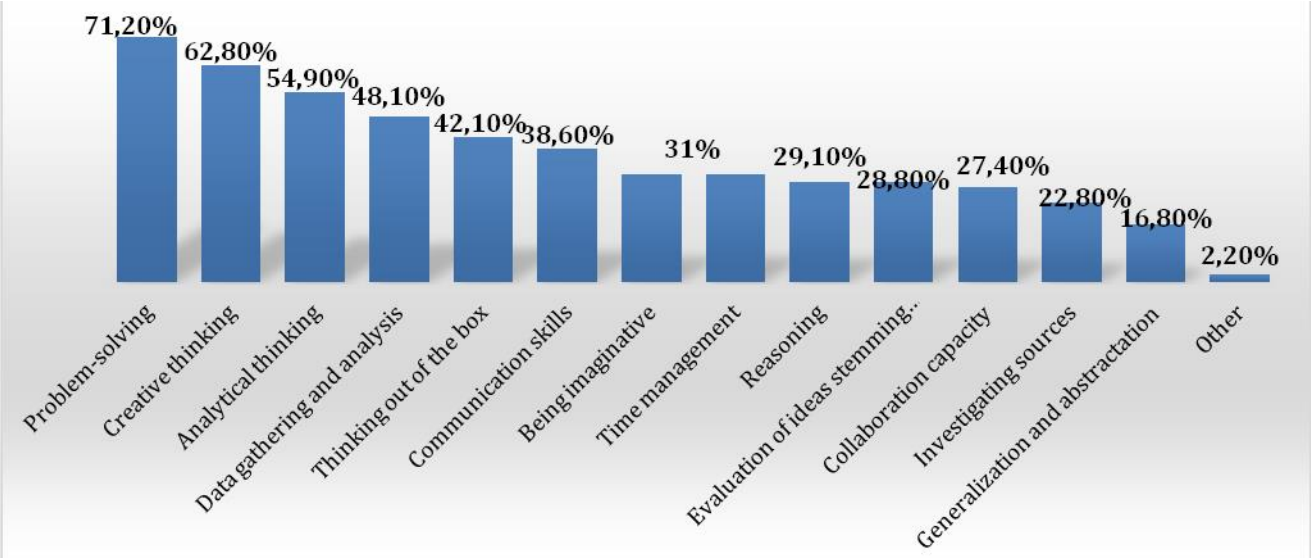


**Figure 5. The most important skills for innovation in ICT careers recognised by students**

*Results on 368 relevant responses involving 3 - 5 selections from the list of suggested innovation skills*

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The above results reveal a slight increase in the neutral position (9% against the 8,4% in the previous question).

Most students consider innovation skills as appropriate for addressing actual industry and societal needs. Specifically, most consider the skills to be very important (52,7%) or important (37,2%) demonstrating an additional slight increase (0,8%) of the students placed at the neutral position.

## 2.3 Learning and teaching approaches currently used for innovation skills building

This section of the survey aimed at documenting student opinions on how certain frameworks support learning experiences.

Five learning design approaches were selected: problem-based learning, active learning, experiential learning, design thinking and gamification in learning.

As shown in the following figure, the most recognizable emerging learning approach is problem-based learning (34,78%). Active and experiential learning (30,98% responses for each) are considered to be of slightly higher benefit with respect the design thinking and gamification in education, possibly demonstrating a lack of understanding or experience of students with the latter.

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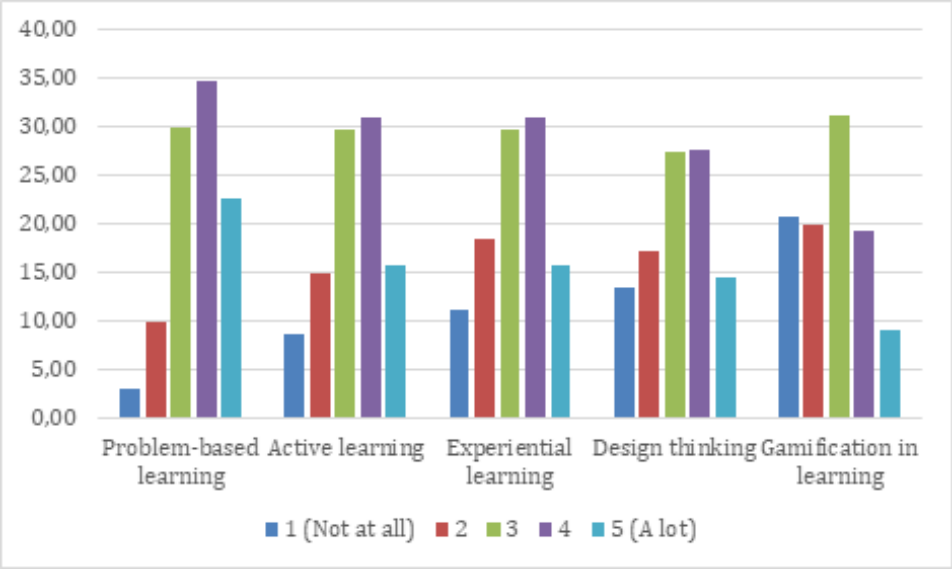


**Figure 6. The level of students' familiarity with each learning design indicated**

Below are some examples of how students use the learning approaches indicated. The examples are student responses to a related open question:

- Using computer programs to solve a problem; for example, using a program that is very effective for constructing maps necessary for various courses.
- Using games in courses.
- Using a gamified virtual meeting space.
- Using design thinking to plan prototype creation.
- Solving problems by doing; experimenting.
- Developing applications to be used in the real world.

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- Using case study evaluation, empirical studies and active learning games.
- Using game elements to increase student engagement and adherence to on-line learning.
- Using problem-based learning in entrepreneurship in groups; identifying the challenges and the overall objective of assignments, investigating diverse solutions and presenting the solution selected by a team.
- Deploying problem-solving in Computer Science; focusing on staying relevant and up-to-date with the latest available technologies.
- Developing a software program in a project that requires pre-design by addressing it as a structured game.
- Playing resource management games that help users build skills on managing resources and processes.
- Building programming skills through games.
- Raising the level of learning through innovation.
- Using a problem-solving environment at the graduate level.
- Working on projects.
- Developing knowledge on artificial intelligence, BCI and related innovative technologies; deploying simulations; designing assignments.
- Solving problems in the context of lab work; for example, developing a program for the benefit of a customer who needs to calculate grocery bills.

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- Experiencing design thinking in web development or other programming activities.
- Designing projects; working on hands-on projects; using the Socratic method; engaging in real-world problem analysis.
- Learning through projects.
- Engaging in active, hands-on works.
- Using interactive audio for MOOC podcasts instead of the usual visual MOOC content.

An interesting fact that emerged from this question is that a large percentage of students (approximately 30%) responded neutrally in relation to the effectiveness of the proposed learning design approaches. This finding may underline the lack of familiarity of students with these educational methods or lack of understanding of their key practical features. This may impede the recognition of theoretical frameworks that support the design and management of lesson plans.

Another interesting finding is that study program design is still widely linked to traditional methods of lesson presentation in which the teacher prefers the frontal modality. The fundamental component of conventional teaching is the so-called "frontal lesson". Educators are in a certain sense "only" in front of the class and the transmission of educational content is entirely entrusted to their knowledge and ability to be clear.

The learning approach mostly used is problem-based learning (33,97%) as shown in the following figure. However, student familiarity with emerging learning approaches doesn’t guarrantee that they have experienced it in practice. In fact, the following figure demonstrates a remarkable decrease of the percentages in relation to the previous question even if the number


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of respondents who placed at the neutral position, level 3 in the scale, presents a slight decrease (0,65%).

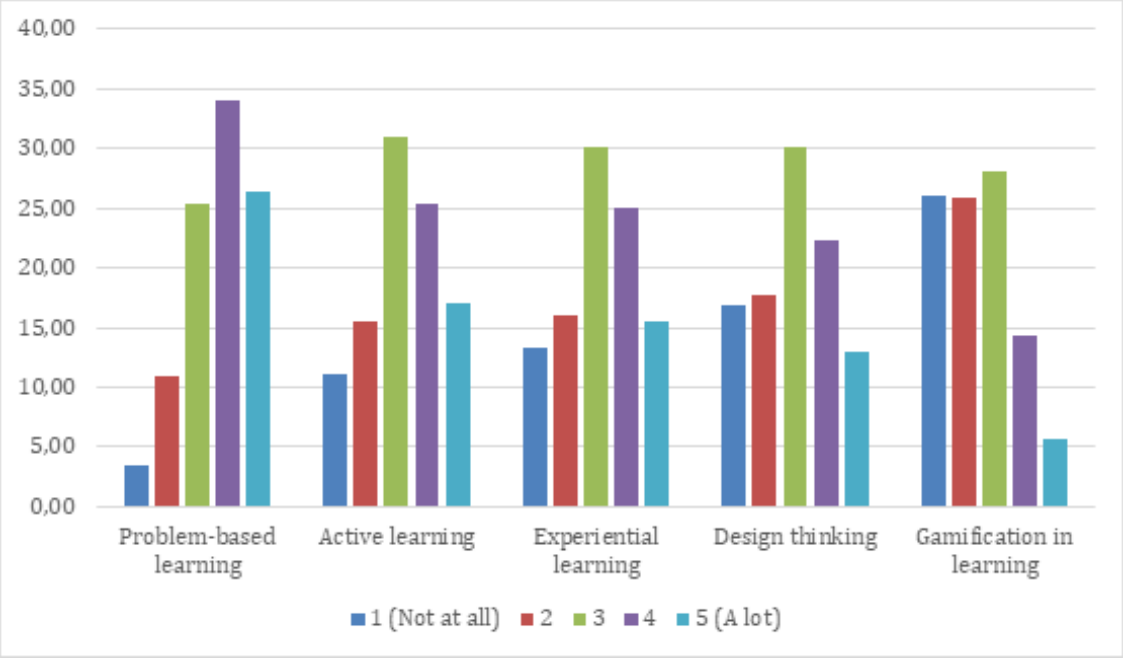


**Figure 7. The learning methods used by students in practice**

This data is confirmed by the fact that students indicate problem-solving (73,4%) as the skill that they mostly develop in their curricula activities during the study path as the following figure shows. In contrast, the other learning approaches are almost neglected (ranked at below 50%) with the expection of analytical thinking, communication skills and creative thinking.

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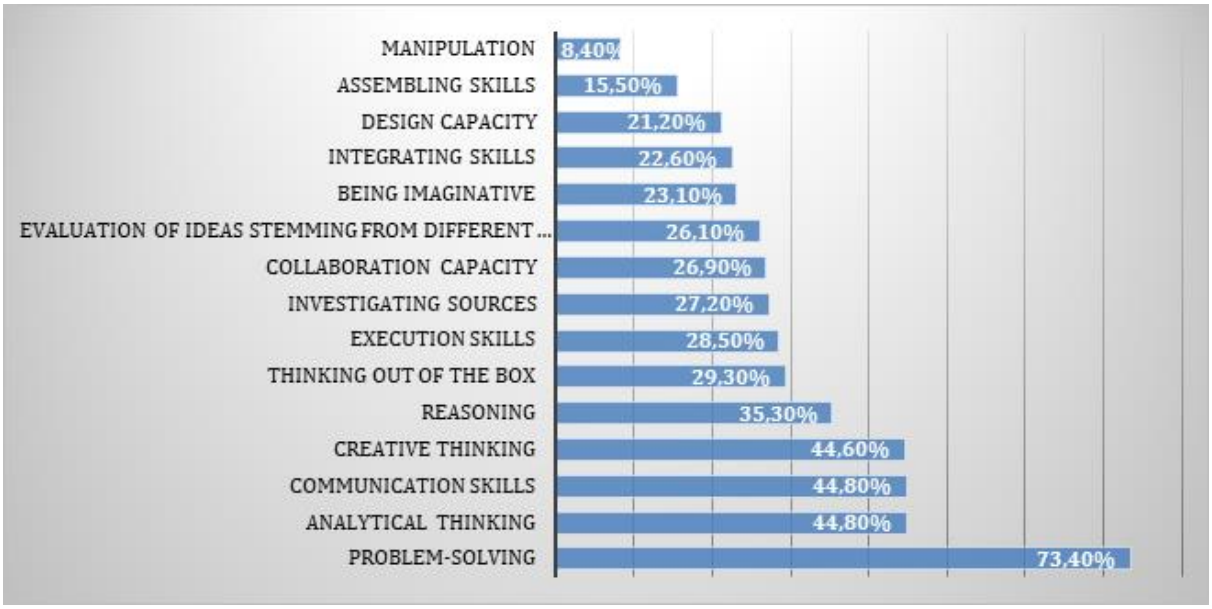


**Figure 8. The skills that students develop through curricula activities**

*Results on 368 relevant responses involving 4 selections from the list of pedagogical methods*

Emerging digital technologies provide a rich range of tools that can be combined or integrated with emerging teaching methods allowing the educator to overcome the limits of traditional teaching. Technology becomes an additional resource that can support and help students in their studies and professional careers.

In this context, the respondents agree (91%) that digital technology can promote and support innovation skills development through on-line learning systems, simulations, games and on-line collaboration systems as the following figure demonstrates.

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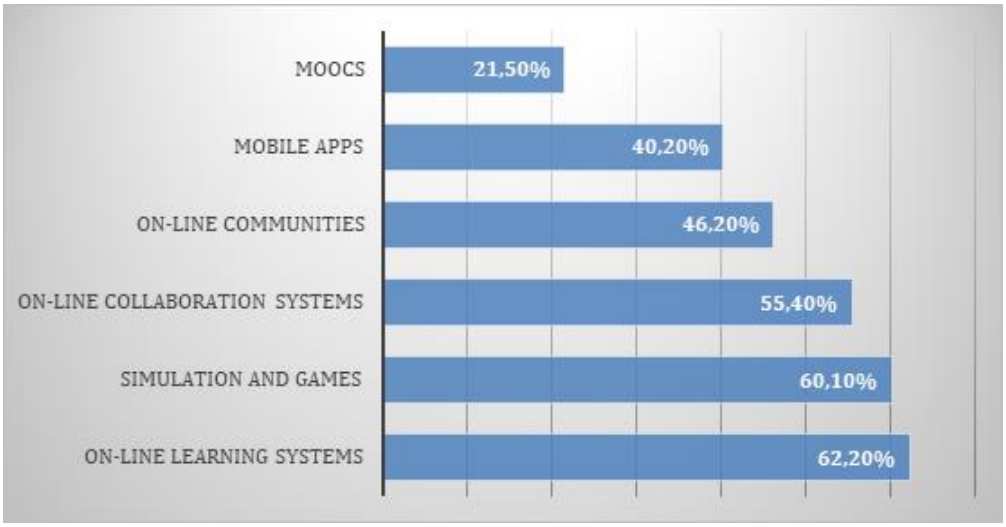


**Figure 9. The digital tools and services which can help build innovation skills.**

However, a small percentage (1,1%) doesn't believe that technology can assist the development of innovation skills while another small group (7,9%) was neutral regarding the same issue.

Some students described examples of practices related to building innovation skills that they were exposed to in their study curricula in a related open question. Practices include:

- Educators presenting key ideas on a theme and subsequently motivating students to think out of the box introducing themselves innovative ideas related to the topic and discussing these ideas in class.
- Developing critical thinking and brainstorming techniques; presenting ideas to get other people on-board.
- Using fun games in courses.

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- Using gamification in ICT courses through tools such as Kahoot® and Quizizz® to make the class more active and exciting.
- Thinking, talking and doing.
- Applying augmented reality technology in teaching to promote motivation and critical thinking ability.
- Encouraging thinking out of the box learning method as it helps students introduce new ideas, expand their imagination and think more clearly and creatively.
- Designing an application or game to solve an existing problem for real clients.
- Using digital tools for collaboration such as Milanote® to work with other team members to sketch new solutions.
- Deploying new technologies in project work; being encouraged to design processes even if the technical support is not fully there yet.
- Working in groups on projects focusing on designing new solutions, implementing and present them.
- Presenting students with societal problems and asking them to select one on which they are encouraged to design and implement a prototype of a product that could solve it or reframe it.
- Being assigned a challenge in the context of ambient computing and asked to design a solution through the Arduino® platform.

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- Building problem-solving skills through programming that allows addressing challenges creatively and efficiently; even though the current pandemic restrictions do not allow collaboration and cooperation with peers working with others, being exposed to new ideas from individuals from different countries and researching information from diverse sources contributes to innovative thinking.
- Actively participating in innovation programs that focus on computer systems and analytical thinking.
- Collaborating in on-line communities and learning their way of thinking while solving a specific problem.
- Engaging in active, as opposed to passive, learning in which every students is encouraged to engage in the subject while lecturers focus more on application rather than theory.
- Engaging in specific subject innovation competitions in which students have to solve a particular problem by designing an idea and building a prototype.
- Engaging in semester-long projects, which may drive creative thinking that helps students think about innovative ways to solve real-life problems through technology.
- Working on collaborative projects in small groups, for example of 3 – 4 individuals, focusing on diverse prevailing problems in the community through creative design and implementation of existing and new ideas in the form of digital software.
- Observing how organisations become innovative; many apply an emerging methodology such as design thinking, agile or lean production described in popular books failing to grasp the symbiotic relationship between creativity, creative process and innovation.

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- Programming solutions for real-world problems.

Several students have highlighted the fact that their universities don't apply any instruments or means for building their innovation skills. As a result, students try to discover their individual way to develop their innovation capacity. Unfortunately, most curricula are generally focused on theoretical learning with limited applications of the theory. Moreover, even if students have been taught subjects with a special focus on developing critical thinking and brainstorming techniques, in the end, related activities mostly focus on building student capacity to present ideas in ordert to get other people on-board.

Even though a small number of respondents don't believe that innovation skills can be relevant for the 21st century most students recognise and emphasize their importance due to the rapid change in our society. In this context, innovation skills will help stabilise and improve the economy of a country and help create technology hubs that will aid in new job creation.

Moreover, the necessity of innoavation skills is evident not only to the modern industrial world for driving economic growth but also in coping with emerging critical issues such as climate change and gender disparity. Therefore, young individuals should be exposed to practices that help develop innovation skills and thinking outside the box to increase their ability to discover new opportunities and react to change.

As humanity and technology evolve, individuals need to start thinking in a more complex and effective way and to realize that imaginative thinking and reasoning is useful in all aspects of life. Through the development of innovation skills, such as critical and analytical thinking, students can improve their ability to work cross-culturally and continuously learn new things.

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In conclusion, the data collected shows that students are still confused on what innovation is, even if they can identify the essential skills that drive it. Furthermore, students do not have a clear understanding of emerging curricular and didactic activities that can support the development of innovative skills.

The study results further show that, with few exceptions, most universities still implement completely traditional teaching methods, based on the dominant use of the frontal lesson, in which the teacher "instructs" and the student "assimilates" knowledge while the "transfer" of knowledge is preferred to its "co-construction".

In fact, although used in some exceptional cases, teaching methods such as design thinking and gamification are not fully exploited in the development of innovative skills.

In the following chapter, the two learning approaches will be described. In addition, their deployment in ICT-INOV for building innovation skills will be discussed.

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# 3. ICT-INOV methodological learning design

This section presents the ICT-INOV methodological learning framework that aims at building the capacity of students to innovate through emerging design thinking approaches combined with gamification elements and supported by digital technologies.

Design thinking encourages students to consider the actual, as opposed to perceived, needs of users and to understand the real parameters of a problem. Gamification promotes student engagement through elements that build motivation in the learning process. Digital technologies enrich student interaction and help provide direct and timely feedback helping students build links between the cause and effect of their choices.

Before presenting the ICT-INOV learning design the section provides an analysis of design thinking and gamification practices in learning.

## 3.1 Design thinking

### 3.1.1 What is design thinking?

Design thinking is an approach to design that aims to introduce human-centred solutions. It goes beyond the traditional user-centred solutions deployed in the design of services and products, which are often based on questionnaire-based studies or interviews. Design thinking develops an understanding on actual, as opposed to perceived, user needs. This is achieved by focusing on the user experience as well as the feelings of the user from her exposure to a proposed solution. The design team members try to put themselves in the shoes of the user by experiencing the challenges that the user faces. For example, if the objective is to design

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solutions for improving the quality of life of inhabitants in a remote village, the designers may opt to spend some days in the village in order to experience the challenges that the inhabitants face.

More than anything, design thinking is about innovation. Design thinkers strive to find solutions that are desirable, feasible and viable [10]. Feasibility refers to the functionality that is possible in the foreseeable future. Viability refers to the possibility of a design becoming a sustainable business model. And desirability refers to what users actually need.

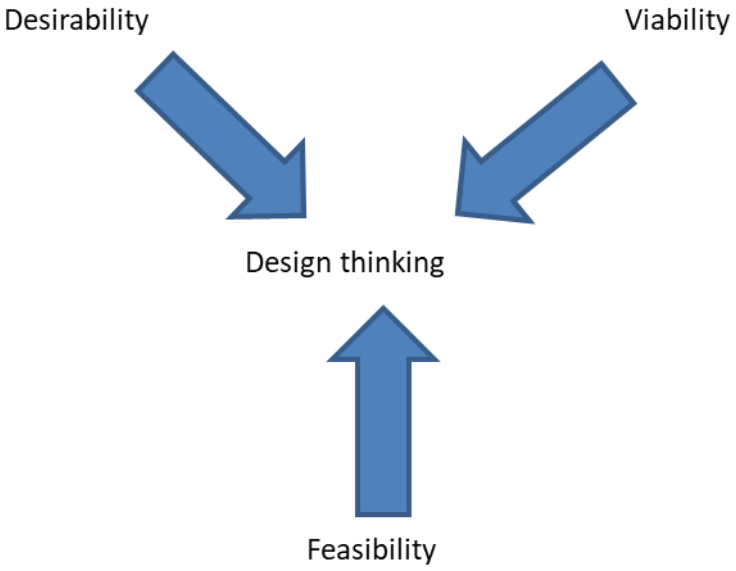


**Figure 10. Visualisation of constraints in design thinking, adapted from [10]**

Another way to look at design thinking is to introduce feasible solutions, namely those at the intersection of design, business and technology.

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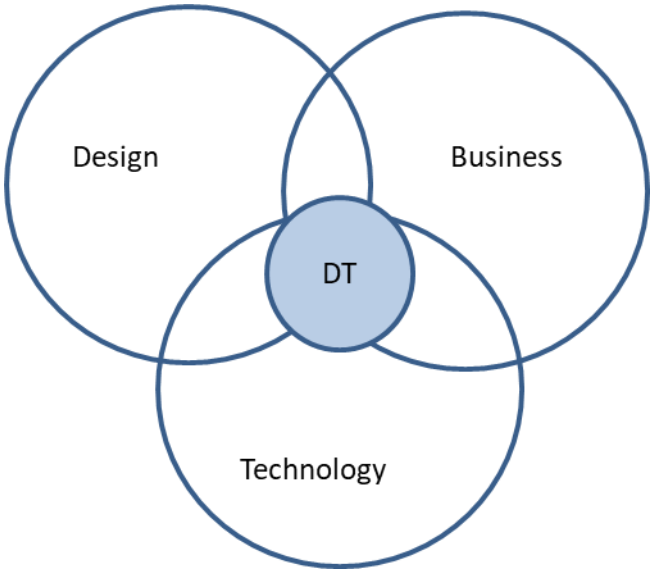


**Figure 11. Design thinking is the intersection of design, business and technology [11]**

Design thinking focuses on understanding user needs through a process of empathy, problem-statement definition, ideation, prototyping and evaluation.

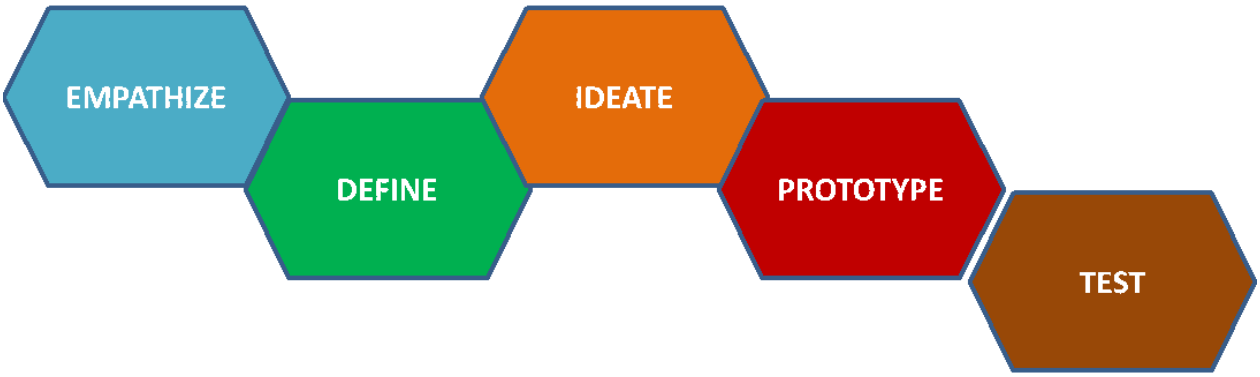


**Figure 12. The stages of design thinking [12], [13]**

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**Empathy** is the heart of design thinking. It refers to connecting with the users for understanding the actual, as opposed to perceived, user needs. Engineers often make the mistake of entering a discussion with a user thinking that they already know the solution. Empathy is about keeping an open mind in the process of understanding the needs of others. It can be practised by observing the users in their everyday activities, engaging with users through interviews and immersing in the users' environment to experience their challenges.

**Problem statement definition** is significant in design thinking, as it is the basis for introducing solutions. Defining a problem accurately allows the design team to focus on the actual user needs. Defining the problem involves using the information collected in the empathy phase, demonstrating user needs and interests. This is integrated with the designers' understanding of the collected information to create a point of view statement. The accurate definition of the point of view may allow the design team to introduce solutions to difficult problems, to which none may appear to exist at first glance. An accurate problem statement definition may help the design team simplify the problem parameters, allowing for a solution to be synthesised. An example that brings this point across is an anecdote by Ford, who designed the first car. When asked about his design experience, he said that his customers believed they needed a faster horse, but in reality, they needed a new transport medium, namely the car [10]. Asking the right question, or, in other words, defining the problem accurately, allowed the design of a more effective solution. Another example stems from the design thinking work at Stanford University. Some years ago, graduate students used design thinking to design a simple, affordable, portable device that looked like a sleeping bag for protecting premature babies in India [14]. The problem is very pressing given the lack of incubators for supporting babies in their first weeks of their lives. The solution was possible because students, through design thinking, asked the right

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question. The question was not how to produce cheap incubators but rather addressing the actual problem at hand, which is maintaining the baby's body temperature at 37 degrees Celcius. This is an example of how defining the problem accurately can allow the design of solutions to very difficult problems.

**Ideation** refers to brainstorming. At this stage, the design team introduces as many potential solutions as possible. Solutions may be mainstream, very innovative or completely out of the box. Creating a rich pool of ideas allows the team to select one for implementation based on specific parameters. The design team may categorise the solutions based on specific aspects and select one from each category before downsizing the pool to a final choice. The solution chosen to be implemented must be possible to turn into a prototype. This is important because the prototype will allow the implementation team to test their ideas with users, who will be able to use hands-on a product and provide feedback.

**Prototyping** refers to creating a discardable prototype of the idea selected for implementation. The prototype does not need to be a complete. It simply needs to allow users to experiment with it. A prototype may be digital or created by simple materials. Its purpose is to be deployed, to generate user feedback in a way that contributes to the design of the final solution and to be discarded. A good prototype generates user reactions to their experiences from using a solution and even the feelings that arise.

**Testing** refers to the evaluation of a prototype and of a final solution. It involves users deploying the prototype and providing feedback that can be exploited by the design team towards enriching a potential solution, bringing the final result closer to user needs.

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### 3.1.2 Where can design thinking be used?

Design thinking offers opportunities to introduce user-centred solutions in both entrepreneurship and social entrepreneurship contexts [15], the latter of which refer to deploying innovation for the greater good. More specifically, design thinking can offer value in [16]:

- Business and new business models, for introducing effective products into the market.
- Social entrepreneurship, for addressing complex social challenges.
- Redefining value, for increasing the value of a product or service for users.
- Quality of life, which can be enriched through user-centered design.
- Evolving markets and behaviours, for better understanding customer and user needs.
- Education, for designing learning experiences that better address student needs and help reach educational objectives.
- Medicine for designing breakthrough therapies that better address patient needs.
- And more.

A very well-known example of using design thinking in business is that if AirBnB [17]. The company was facing difficulties in 2009 with flat revenues. To understand the cause of the problem, service designers reviewed 40 listings and observed that they had not good photos in common. The hypothesis was that customers did not rent the properties because they did not have a clear picture of the spaces based on the available photos. As a next step, the designers performed an experiment. They took good photos of the properties and updated the listings.


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After this property leases increased and the company is now highly successful. This example demonstrates that focusing on the user experience from the use of the service can play an important role in increasing value for customers.

Another well-known example of design thinking in social entrepreneurship contexts is related to an initiative undertaken by the government of Vietnam to reduce malnutrition among children in rural areas. At that time, 65% of children under 5 suffered from malnutrition. The work was conducted by Jerry Sternin of the Positive Deviance Initiative and his wife, Monique. The researchers used an approach called positive deviance that uses existing, sustainable practices that families with no malnourished children followed despite the fact that they were very poor. They noticed patterns in the collection and preparation of food. More specifically, they noticed that along with the greens that these families from rice paddies also collected tiny shrimps, crabs and snails which provided a source of protein. Most families did not use this source of food because it was considered unsafe. Based on these findings, they trained the inhabitants in rural areas to adapt their cooking practices. The result was that 80% of 1.000 children enrolled in the program were adequately nourished [18].

The above demonstrates how design thinking has broad applicability in both business and social contexts. It further indicates that understanding the user experiences and challenges and accurately defining a problem can lead to introducing sustainable solutions to complex challenges that traditional design methods have failed to address.

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### 3.1.3 All problems are design problems: the importance of design in innovation

The young generation of today will be challenged to address complex issues of the 21st century. For example, the United Nations sustainability goals include eradicating poverty and hunger, promoting good health and well-being, ensuring access to quality education, affordable and clean energy, innovation, responsible consumption and production, sustainable cities and communities, gender equality, climate action, preservation of life on land and underwater and more [19]. Technology, particularly ICT, can be a significant part of solutions introduced to solve these problems. For this reason, it is important to build the innovation capacity of students in order to empower them to turn their ideas into action upon transitioning into the world of work. Solving today's problems, however, cannot be solely based on technology. It requires taking a high-level view of a challenge and having a design mindset. All problems today could be considered as design problems [10]. For this reason, higher education curricula can benefit from design skill-building activities that help students harvest their innovation potential.

### 3.1.4 Creative teams

Design thinking is heavily based on teams. While large teams are common in the implementation phase of a project, small and focused ones are preferable in the design phase [10]. Each team member has a role. Each individual brings different strengths to a team. For example, an individual may be a good coordinator, researcher of ideas, resource investigator, evaluator of sources, implementer, finisher, team player, specialist, shaper, finisher of a product and more [20]. Typically, most individuals are skilled in one of the above and a little less in a second capacity. However, a team requires all these roles to function properly, which highlights the need of collaboration for completing a project.

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Teams collaborate best in face-to-face settings, in which members can share and build on each other's ideas. This is the case in all collaboration contexts, but it is particularly important in design thinking where individuals ideate and brainstorm, evaluate ideas, synthesise solutions and test prototypes. In today's digital world, in which teams may be distributed, collaboration takes place not only face-to-face but also over the internet. Team members may be located in different rooms, buildings or countries. While digital technology does help in collaboration, classic tools such as email or videoconferencing can only contribute up to a point to group work taking place at a distance. Traditional online tools help in the storing and sharing of data. However, what motivates teams working from a distance is the capacity of generating ideas, brainstorming and building consensus [10]. Lately, some tools have emerged that support the online sharing of ideas among team members [21]. These online tools allow individuals to share ideas and build on each other's contributions in real-time digitally. Social media is also used sometimes for team collaboration since it allows individuals to network and publish, although they are not designed as collaboration tools. ICT-INOV aims to further contribute to online collaboration through the design and implementation of a digital service that support students in being creative throughout the design thinking phases. The tool will complement collaboration taking place face-to-face, allowing students to continue to be creative in groups beyond the classroom. This will facilitate the design process as it will allow team members to contribute to the brainstorming process not only in the context of formal face-to-face meetings but at any times that ideas are generated, often out of formal schedule.

### 3.1.5 Use technology to change the world

Innovation is evident in all parts of life. The creative thinking of individuals can help shape the future, improve quality of life, make medical breakthroughs, enrich the educational design,

address social challenges, fight climate change and more. Innovation-related sectors, such as ICT, are expected to drive economic growth in the near future. For every job that is created in innovation-related sectors, another five are expected to be created in others [22]. Companies in a high growth path create more indirect than direct jobs, positively affecting their communities.

The ICT sector has been growing rapidly as a result of technological evolution. In ICT, what is considered new today may be obsolete just a few years down the road. For example, fast speed internet was considered a breakthrough some years ago, but today everyone takes it for granted. Mobile phones have evolved from devices with buttons to smartphones that have the capabilities of a small computer. Networks have evolved from 3 to 4 and to 5G in only a few years, driving both the demand and supply for ever more powerful digital applications that address diverse needs in business, everyday life, entertainment, advanced health care, richer educational facilities and channels, enriched communication, broader economic activity that can expand online, transformed transportation and more. This growth has also contributed to high growth in the creation of high demand for ICT professionals, with some studies estimating a current lack of approximately 900.000 ICT professionals in Europe.

The above highlight the importance of ICT as an innovation sector to societal growth and well-being. Towards this end, the ICT-INOV project promotes educational design that fosters the innovation potential of ICT students towards addressing the pressing challenges of society and business opportunities that promote sustainable development.

## 3.2 Gamification

Gamification refers to using game elements in business, organisations and services, including education, to promote user motivation and engagement [23] [24].

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### 3.2.1 Games and play

Gamification is based on the concepts of play and games. Play does not have structure and appears everywhere in nature, evident throughout the animal kingdom. For example, play is throwing a ball in the air for no apparent reason other than amusement. On the other hand, games have structure, rules and usually a victory condition. Games are systems that include as elements players, mechanisms, decisions and goals [25]. Gameplay involves interaction between these elements that lead to different behaviours and produce different results. To a great extent, games involve the evaluation of choices by the player, which is also what individuals practice daily in real life.

For this reason, games help students make connections between the cause and effect of their decisions, which can contribute to critical thinking and learning. An example of a game with structure and rules is the well-known Monopoly [26], in which individuals aim to collect game money by purchasing real estate and charging rent. Different types of play and games exist, such as body play, social play, imaginative play, spectator play and more [27].

The engagement in games and play is internally motivated in the sense that individuals participate in them voluntarily [27]. Play is essential to humans and it is one of the first forms of communication for newborn babies that cannot yet communicate in other ways, for example, by speaking. This early way of communication, through which babies develop their first bonds with parents and others, follows an individual through life. Each individual has a “play history”, which refers to how much she or he has played in their lifetime. Play and games appear to have an impact on an individual’s ability to become an active member of society. Individuals with a poor play history may face challenges in becoming socially integrated. This is not surprising as


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games are highly interactive, helping individuals build trust and understanding within a specific context of rules, which is the basis for communication and collaboration in broad contexts, including work [27]. Games and play have universal signs that both animals and individuals seem to recognise. For example, it is possible to recognise that a dog wishes to play by its wagging tail or an individual by her facial expression.

Despite perceptions, play and games are not only meant for children. All individuals engage in games and play, including adults. In fact, the capacity of humans to engage in games and play throughout their lifetime contributes to their adaptability in evolving situations.

The benefits of games on humans are not completely understood. However, in addition to contributing to socialisation, games are considered to contribute to problem-solving skills desirable in the 21st century and also practical skills, such as performing specific processes with accuracy, which can be useful to diverse professional roles ranging from mechanics to medicine.

### 3.2.2 Serious games

Serious games are games that are designed for a purpose other than entertainment [28]. Serious games are described as applications that, if properly designed, are accessible and recognisable learning solutions for a broad range of learning needs. They are a natural way for building knowledge and skills in a young generation that is digitally native [29]. They can contribute to the development of high order thinking skills such as critical thinking, analytical thinking, problem-solving and decision making.

Serious games can address wide objectives such as:

- Education.

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- Training.
- Crisis management.
- Business.
- Marketing.
- Medicine.
- Research.
- Awareness building and promoting positive attitudes.
- And more.

In learning games can be deployed in two ways:

- Use games designed for entertainment for enriching specific learning experiences.
- Use serious games that have been design for educational purposes.

When games designed for entertainment are deployed in learning, it is possible that the learning process may need to be adapted to the game content, functionality and capabilities. For example, if a game covers only specific content in mathematics or history, the educator may need to adapt learning accordingly deviating from educational objectives. Serious games designed for learning take into account educational needs and goals. For this reason, there is less need to adapt the learning process to a game since the game itself is adapted to the learning process.


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Serious games can be both off-line, for example, they can be board games or digital. The idea of using games in educational contexts is not new. It originated in the 1970s when digital games emerged.

The advantages of serious games are many [30]:

- They involve puzzles, which everyone like to be challenged with.
- They provide real-time feedback related to student actions, helping them link the cause and effect of their choices.
- They involve elements of fantasy that drives student motivation to engage in learning.
- They contribute to the effective understanding of concepts and data.
- They involve role-playing, which prepares students for real-life professional and other activities.
- They allow the development of dynamic presentations of real-world events, linking learning to real life.
- They can be deployed for building theoretical knowledge, practical and soft skills such as problem-solving and critical thinking.
- They can be used for initial training in dangerous processes and practices. For example, a pilot is initially trained in a flight simulator before flying a plane; a surgeon is exposed to a delicate procedure in a virtual simulator before performing it on patients.
- They can be used when deploying physical spaces for training is expensive. For example, closing a factory plant for training new employees is expensive. Training them initially in

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a virtual environment before exposing them to the physical infrastructures is more cost-efficient and safe.

- They can promote positive attitudes.
- They can be used for evaluation foregoing the danger of making serious mistakes in real-time. In addition, evaluation through games that simulate real-world practices does not introduce the distortion that a typical exam does as a result of being delivered in a non-realistic environment.
- They encourage students to learn, create and collaborate.

Serious games are not a new idea. The idea of using digital games in learning emerged when digital games emerged in 1970. The size of the digital games industry is expanding at a fast pace and, according to some research, is expected to reach $436b in 2027 significantly exceeding the 2019 business cycle of $129b [31]. The size of the digital games market for educational purposes, however, is smaller and reaches $2.4b [32]. This demonstrates that there is room for improvement in deploying serious games in learning contexts. Towards this end, the European Commission promotes initiatives that foster the links between industry and academia for the development of quality digital educational content in the form of games.

Serious games offer significant advantages in learning. Some researchers are also critical of the use of games as learning tools. The main concern is that students may make random choices when engaged in a game rather than conscious decisions. For example, students may click on the screen until the accidentally select the correct answer. Random choices do not promote learning. For this reason, it is important to assess how consciously students make decisions towards reaching a learning objective. To overcome this limitation, some researchers suggest


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that games be used within larger learning cycles that involve gameplay followed by debriefing sessions in which the educator engages students in interviews to evaluate their level of conscious engagement [33].

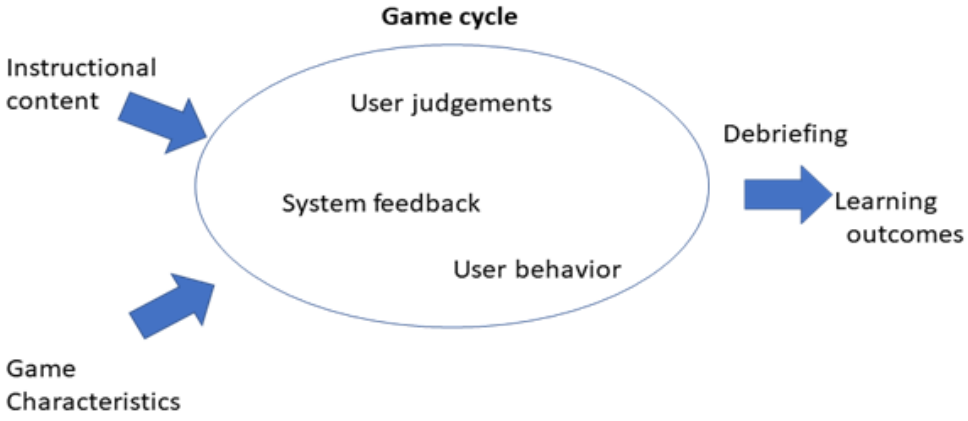


**Figure 13. The Garris cycle [33] for introducing games into the learning process**

### 3.2.3 Related pedagogical theories

Serious games are based on the concept of constructionism [34], which advocates that knowledge is not transferred but rather it is synthesised. According to constructionism the educator is a guide for the student who discovers new knowledge. Constructionism is based on the ideas of constructivism [35] introduced by Jean Piaget, who performed research on the cognitive development of children. Piaget noticed that while children systematically provided wrong answers to given problems at a specific age they systematically provided correct answers a few years later. This led to the observation that the human brain develops in stages. Piaget defined the following developmental stages:


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- Sensor motor phase (ages 0 – 2), in which children use their senses to understand the world around them.
- Magical thinking phase (ages 2 – 7), in which children understand the world but do not try to see why it works in a specific way; rather, they accept it as “magic”.
- Logical thinking phase (ages 7 – 11), in which children develop logical reasoning competencies.
- Abstract thinking phase (ages 11 – 16), in which children can engage with abstract concepts.

Based on the theories and constructivism and constructionism, Papert introduced the concept of “microworlds” [34]. Microworlds are simplified abstractions of the real-world that challenge students to engage in problem-solving. Given the fact that children can only process limited amounts of information, microworlds involve only elements that are necessary for solving a specific problem removing unnecessary information that is regarded as “noise”. Microworlds include objects and rules that affect the relationships between them. One of the best-known microworlds is that of the turtle, which encourages learners to build knowledge on Euclidian geometry. The main object in the microworld is a turtle, which can be considered as an avatar that the child uses to interact with the microworld to draw geometrical shapes. The microworld further includes a pen that is controlled by the commands up, down, turn left, turn right, forward and backward. These commands are sufficient for the task at hand, namely, drawing shapes. Microworlds could be considered the predecessors of learning simulations, virtual learning labs and digital learning games.

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Using microworlds or digital learning games is an active way of learning. Active learning is a pedagogical theory in which learners build knowledge by doing in a way that involves more than seeing and listening [36]. In active learning, learners adopt roles, explore, collaborate, solve problems, visit sites of interest and more. Through analysis, synthesis and evaluation, they build knowledge, skills and positive attitudes. Active learning offers several advantages to students:

- It reinforces important concepts and skills.
- It provides frequent and immediate feedback.
- It helps students establish connections with the educational material, increasing their motivation to learn.
- It promotes collaboration and teamwork and builds a sense of community in the classroom
- It develops self-esteem through student discussions and engagement with peers and educators.

Active learning helps develop higher-order thinking skills as these are defined in Bloom's taxonomy [37] [38]. This model, which was introduced in 1956, recognises six categories of skills and abilities: knowledge, comprehension, application, analysis, synthesis and evaluation. Learning initially focuses on remembering and understanding the content. These are typically the objectives of traditional educational methods. Once these levels have been achieved, learning focuses on higher functions of the brain, which include applying the new knowledge in practical situations, analysing and evaluating it towards creating new, original work. These are the objectives of active learning design.

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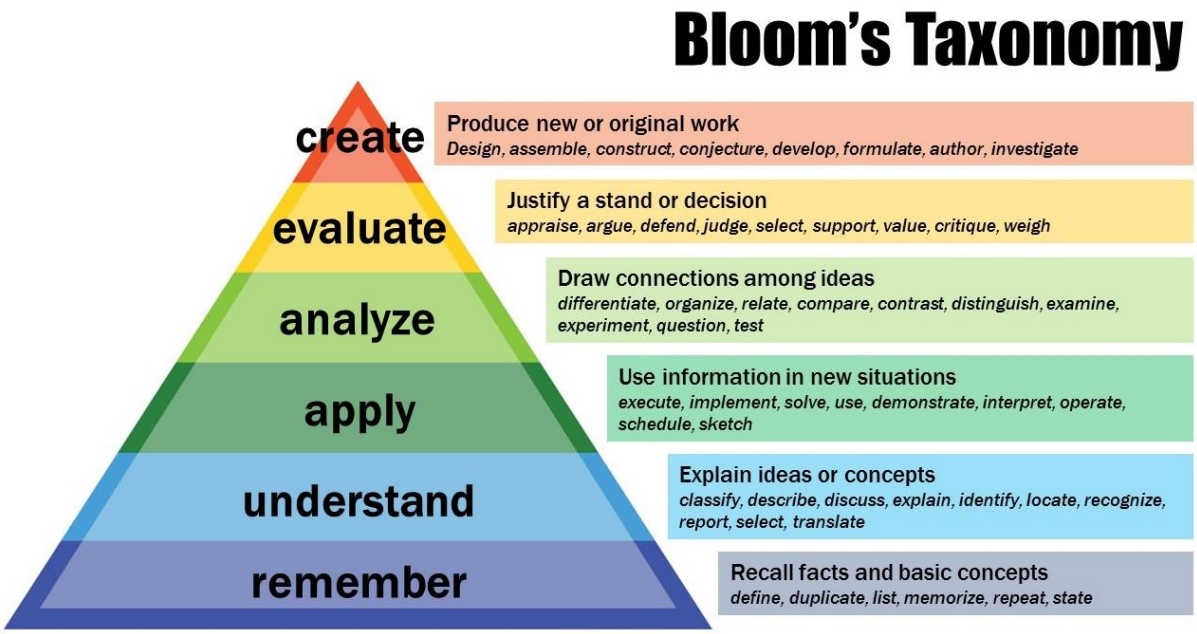


**Figure 14. Bloom's Taxonomy (available through Creative Commons)**

Part of active learning is problem-based learning [39]. In this approach, learners build knowledge by solving a problem that usually is non-trivial and open-ended. Problem-solving is one of the most advanced capabilities of the human brain. Similar to active learning, the benefits of problem-based learning are:

- It helps students establish connections with the learning material.
- It helps link education to the real world by addressing problems inspired by real life.
- It builds knowledge in a manner that simulates future roles, supporting the transferability of knowledge from the academic environment to the world of work.
- It promotes critical and analytical thinking [40].

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- It encourages students to evaluate information that stems from different sources.
- It promotes collaboration and teamwork.
- It promotes independent and self-learning [39].
- It allows students to apply knowledge and helps them establish connections between education and real life [41].
- It encourages students to discuss and justify their choices and solutions.

Problem-based learning has its roots in medical education. In the 1960s, educators at McMaster University, Hamilton observed that the content in the first three years of study was not related to clinical medicine [42]. As a result, they endeavoured to promote the practical application of new knowledge and its use in a manner that simulates future roles. The learning involved the studying of actual patient cases. 80% of medical schools in the USA today apply this method. Problem-based learning is since being deployed widely in secondary and tertiary education in broad sectors that include engineering, law, entrepreneurship, social sciences and more, in which students learn by studying real-life cases.

There are different ways to apply problem-based learning. However, some common elements are evident in most practical applications. The steps for problem-based learning are the following:

- Stating the problem, namely the learning goal.
- Stating what is already known.
- Making hypotheses.

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- Brainstorming.
- Evaluating ideas.
- Breaking down a problem into smaller tasks.
- Synthesising solutions through collaboration and integration of knowledge from diverse fields [43].

Problem-based and active learning are student-centred and they are driven by curiosity for knowledge. In this context, the role of the educator in problem-based and active learning evolves. The educator:

- Guides and supports.
- Encourages and build student self-confidence in their problem-solving capacity.
- Coordinates learning.
- Broadens student understanding of the subject matter by answering questions.

Finally, experiential learning is another related methodological learning approach. In experiential learning, knowledge development starts from an event that drives students to review their perceptions of the world [44 - 48]. Kolb defined a learning cycle that includes concrete experience, reflective observation, abstract conceptualisation and active experimentation. According to Kolb, students may enter the cycle at any of these steps and continue through the rest to build knowledge and change.

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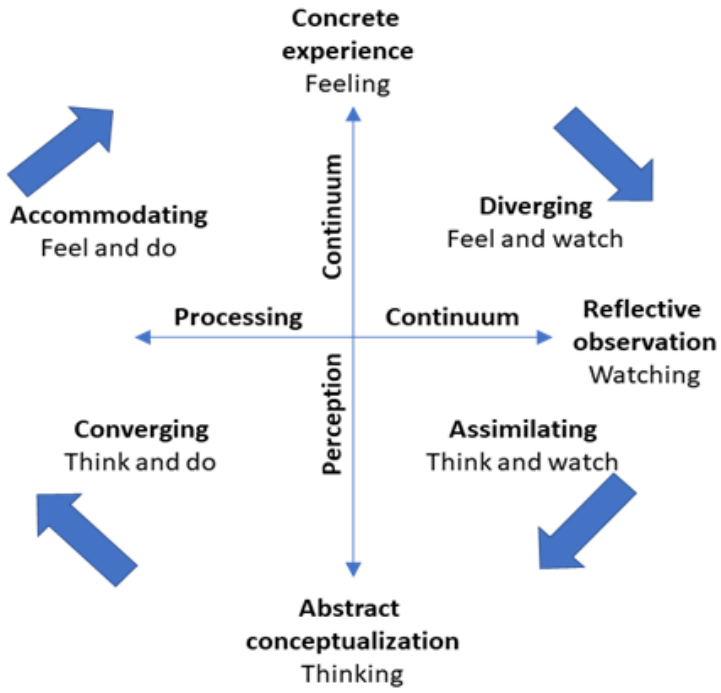


**Figure 15. Kolb learning styles [3]**

Based on the 4 elements of his model, Kolb argues that effective learning entails the possession of four different abilities. They are concrete experience abilities, reflective observation abilities, abstract conceptualisation abilities and active experimentation abilities. These four abilities manifest in four basic learning styles involving learning characteristics on two different continuing learning: one is from the concrete experience to the abstract conceptualisation and the other from the active experimentation to reflective observation. As a result, the 4 basic learning styles are converger, diverger, assimilator and accommodator [3]. Tennant provides a a further analysis of the identified learning styles, as summarized in the following table [51].

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| Learning style | Learning characteristic | Description |
|---|---|---|
| Converger | Abstract conceptualisation + Active experimentation | Strong in the practical application of ideas. Able to focus on hypo-deductive reasoning on specific problems. Unemotional. Has narrow interests. |
| Diverger | Concrete experience + Reflective observation | Strong in imaginative ability. Good at generating ideas and seeing things from different perspectives. Interested in people. Broad cultural interests. |
| Assimilator | Abstract conceptualization + Reflective observation | Strong ability to create theoretical models. Excels in inductive reasoning. Concerned with abstract concepts rather than people. |
| Accommodator | Concrete experience + Active experimentation | Greatest strength in doing things. More of a risk-taker. |

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| | | |
|---|---|---|
| | | Performs well when required to react to immediate circumstances.<br>Solves problems intuitively. |

**Table 1. Tennant's description of learning styles [51]**

Understanding students' learning style helps discovering their strengths and weaknesses in experiencing a learning situation. While understanding of weakness guides a learner to pursue proficiency through other learning modes, knowledge of strengths may directly impact areas such as selecting one's career. According to Knox [52], such knowledge helps an individual make transitions to higher levels of personal and cognitive functioning.

On the other hand, understanding of learning styles in a classroom enables a teacher to select or develop learning material that best fits the diversity of the classroom. The very idea of experiential learning directs an educator's attention to the importance of experience in learning and guards against limiting teaching to a mere presentation of information and facts.

### 3.2.4 Gamification

Gamification is a more general term than serious games. As stated above, gamification refers to the deployment of game elements in other contexts, such as business and learning. However, the term serious games usually are usually linked to digital applications. On the other hand, gamification may refer to game elements integrated into services, such as internet-based, or processes. Examples of services that may be gamified include:

- Entertainment.
- Marketing.

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- Digital games.
- Communities.
- MOOCs.
- Learning management systems.
- Business processes.
- And more.

Examples of gamification elements that may be integrated into these processes include[23]:

- Meaningful and clear missions.
- Rules and structure.
- Rewards.
- A sense of progress and success.
- Tasks which are challenging but achievable.
- A sense of affiliation and team work.
- Immersion.
- Socialisation.
- Immediate feedback.
- Social recognition.
- And more.

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One of the most well-known examples of gamification in corporate training is that of the company Deloitte, which developed the Deloitte Leadership Academy for corporate training of its employees in 2008 [49]. This digital initiative is aimed at motivating employees to engage in training through gamification. The gamified learning design was very successful. In the timeframe from 2008 to 2013, employee participation increased, reaching 20.000 users. In addition, there was a 37% increase in the number of returning users each week [50].

The digital training service deployed traditional content in the form of videos, text and in-depth courses. It also included gamification elements, such as missions, badges and leader boards, which led to higher user engagement and an increased likelihood of completing the online training programs. Users received badges for completing a learning module. In addition, they received surprise "snowflake" badges that were unlocked only when they achieved specific goals. In addition, the academy was innovative in its handling of leader boards. Leader boards can be counterproductive as strong players are always in the top spots, with new players having little opportunity to beat them. To alleviate this challenge, the academic reset the leader boards each week, which allowed all users to start again with equal opportunity to be distinguished.

The academy was linked to higher success of participants. There was a correlation between engagement in the platform and promotions. Another sign of the platform's success was that it was deployed not only by junior but also senior employees.

This initiative showed that gamification can be an asset in increasing engagement in training or other business practices if it is well designed, taking into account overall missions and the interests of participants.

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## 3.3 The ICT-INOV digital learning intervention for fostering innovation through gamified design thinking

The ICT-INOV project aims to introduce a learning intervention that helps build student capacity to synthesise innovative and entrepreneurial solutions in business and social entrepreneurship contexts to create value for individuals and communities, enrich life quality and address the complex challenges of the 21st century. This will be pursued through active learning design in which learners will be challenged to design interventions by thinking out of the box, working in teams, brainstorming, synthesizing ideas and evaluating solutions.

ICT-INOV aims to develop innovation skills by fostering collaboration in **design thinking contexts** both in and outside of the classroom through a learning intervention that promotes team work, brainstorming and building on each other's ideas from anywhere and anytime. Student engagement is further motivated through **gamification elements** throughout the learning process that reward current and future long-term engagement in innovation building activities through gamifing elements such as clear goals and objectives linked to the educational process, rewards, recognition, roles, team work and more.

The integrated **gamified design thinking approach** proposed by the project offers learning benefits on the development of theoretical knowledge linked to curricula as well as soft skills demanded by industry and society for addressing complex 21$^{st}$ century challenges, such as critical thinking, analytical thinking, team work, independent work, evaluation of resources and more.

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The ICT-INOV learning intervention is vertical, comprehensively addressing challenges related to the development of innovation capacity, including the lack of physical and digital infrastructures and the need for instructor training. Specifically, the project develops:

**Digital design thinking labs.** Labs will be created at the 8 ICT-INOV partner universities located in Asia, namely the University of Malaya (Malaysia), the University Tenaga Nasional (Malaysia), the National University of Computer and Emerging Sciences (Pakistan), ISRA University (Pakistan), Tribhuvan University (Nepal), Kathmandu University (Nepal), Hanoi University (Vietnam) and Von Neumann Institute (Vietnam). They will include equipment that supports student collaboration and educator support of the learning process in the context of gamified design thinking activities towards the analysis, design, synthesis and evaluation of innovative solutions. Equipment will be carefully selected by each partner so that it is in-line with the project proposal, complements existing infrastructure, supports and facilitates the evolution of curricula courses through the integration of design thinking and, in general, enriches communication and interaction in the learning process. All equipment will be placed in a single lab for the benefit of students. The labs are expected to be built in time for deploying during the project implementation period, and not after.

**Gamified digital learning platform for innovation**. A gamified digital learning platform will be designed and implemented for facilitating student collaboration in and outside of the classroom, face-to-face or in distributed teams, promoting group work towards innovation.

The platform will introduce services for both educators and students for supporting innovation building activities. For students, the platform will promote collaboration in innovation skill development activities by supporting design thinking practices and steps. The platform will


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support team work in and out of the classroom through services that allow the real-time collabofation of team members through jointly owned workspaces. Gamification elements will encourage student engagement. For educators, the platform will provide services that allow the development of gamified design thinking activities for innovation. It will further support educators in monitoring student work and allow them to provide feedback throughout the learning process.

**Open educationa content in the form of activities**. Complete learning activities will be designed and published through the gamified digital learning platform. The learning activities will be designed to be directly used in existing courses and activities, contribvuting to the updating of educational practices at partner universities for strengthening their capacity to foster innovation skills among students and graduates. Learning activities to be developed by the consortium will further serve as inspiration for educators and other stakeholders towards designing additional learning modules that promote student innovation in active contexts.

**Instructor training and community building for capacity strenthening**. Instructor training will take place in an ongoing manner with the objective of developing the capacity of educators and educational organisations to adopt learning design that promotes innovation among students by deploying design thinking approaches. Community events will further promote the exchange of good practices, the sharing of knowledge and the collective building of capacity to design and implement innovation fostering learning activities.

Below is a more detailed description of the educational features of the proposed digital learning intervention.

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### 3.3.1 Innovation fostering activities for students

The proposed learning intervention will promote the innovation potential of students through through gamified design thinking. While the intervention follows the well accepted design thinking steps of problem discovery, empathy, problem statement definition, ideation, prototyping and evaluation, it should be noted that it is flexible enough to allow educators to adapt it to the needs of their students and the objectives of their course. Educators will be allowed to define the design thinking steps that will be deployed in their course. This open approach also allows for different approaches to design thinking to be integrated into learning. Below is a description of the foreseen educational benefits that help build innovation skills among students.

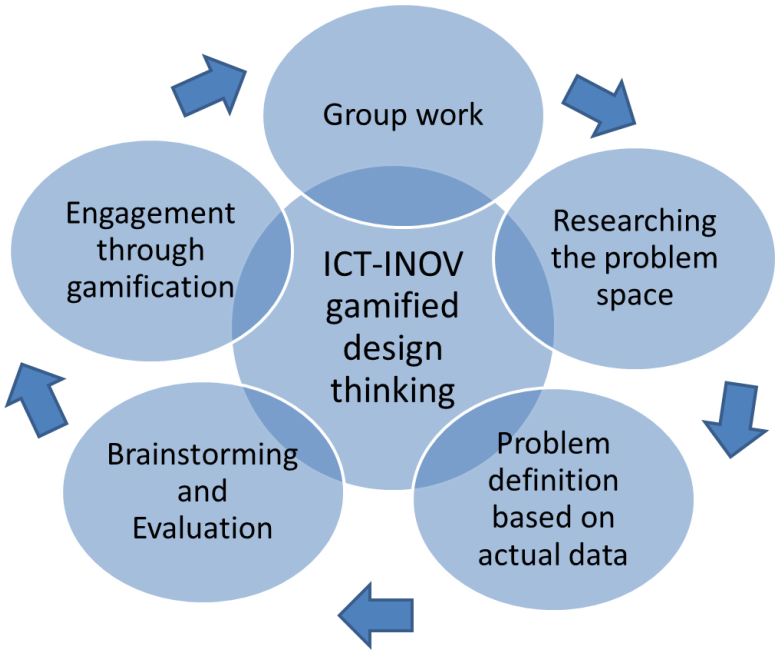


**Figure 16. The ICT-INOV gamified learning methodology for building innovation skills.**

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**Group work.** The ICT-INOV activities will be highly collaborative. Innovation is best promoted through teams that collectively offe

r complementary skills and knowledge towards addressing complex challenges. ICT-INOV will support collaboration both in the classroom and remotely through digital services that support the work of distributed or remote teams in real-time. This is particularly relevant in the era of COVID-19 where students often perform at least some of their classwork from home. The collaboration will be supported through the services presented below in relation to idea-sharing. It will be further supported through tools for online communication, such as chats.

**Understanding the problem space**. Students will research the problem area in order to understand the parameters, the challenges and the different aspects. This work will enable students to document the problem before brainstorming on a solution. Students will seek information in diverse ways. For example, they may research the internet for articles, images, videos or links that describe the problem space. They may also engage in empathic for understanding the real, as opposed to perceived, needs of users, such as interviews, personal communication or immersion in the users' environment. Students will be able to describe their ideas by using diverse media, such as text, images, or video, for best depicting a clear problem description.

**Facilitating brainstorming**. Students will be able to post ideas, see the posts of team members in real-time and build on each other's suggestions contributing to a joint solution. In addition, they will be able to group ideas by colour coding them, edit them and delet them. This will be achieved through a common working space or canvas that team members will be able to use jointly and in real-time. In other words, team members will be able to see annotations made by


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their peers at the time they are made and post additional ideas to further the team discussion towards introducing a solution. This activity will foster the ideation phase of design thinking, in which designers contribute as many ideas as possible to create a rich pool of potential implementations that they later evaluate.

**Defining a problem based on its actual parameters**. Using the results of the brainstorming or ideation activities, students will introduce a problem-statement definition that integrates the information they have received from users as well as their own point of view. The problem statement definition will be used for identifying possible implementation approaches in later steps.

**Prototyping and evaluation**. Students will use the platform to post ideas on generating a prototype of a solution that addresses the problem statement definition. The prototype will be designed in a manner that allows users to interact with it for generating feedback, with includes experiences and feelings. Students will also be able to post the evaluation findings on the ICT-INOV digital learning platform for completing their design thinking activities and potentially starting a new design cycle based on feedback.

The ICT-INOV learning intervention will support different approaches to prototyping, which are suitable in different educational contexts. For example, for software courses prototyping may be in the form of application development. For hardware or engineering courses, ICT-INOV will support prototyping in the form robotics constructions, potentially programmable, to be implemented by students in the ICT-INOV labs. For creativity and communication courses, prototyping may be supported through solution description posters, storyboards, sketches, animations or other method.

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**Engagement motivators**. Gamification elements will promote the engagement of students in the learner process. Gamification will reward and encourage participation. The following elements of gamification are considered:

- **Points**. Participants will receive points by upvoting or downvoting the contributions of peers. For example, students may upvote or downvote the contributions of other students towards solution synthesis. Educators may upvote activities designed by pears. When an individual receives a certain number of upvotes, they will gain the right to engage in the upvoting and downvoting process.
- **Experience**. Participants will collect experience by engaging in design thinking activities through the platform, such as posting ideas, reviewing the contributions of others and providing feedback, asking for help by peers, and more. Students will use experience points to unlock features such as the support of different colours of notes that allow them to organize their ideas, different board styles, different avatar background colours, and different avatar text colours.
- **Challenges**. Clear objectives will help students to engage students in interesting and complex tasks.
- **Constructive feedback**. The platform will support feedback generation for students, to be provided by educators or peers upon request.
- **Context**. Scenarios will be inspired by real life, encouraging students to introduce solutions to relevant industry or societal challenges, linking education to the real world.

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### 3.3.2 Innovation fostering activities for educators

Educators will use the ICT-INOV platform to design learning activities that foster the innovation capacity of their students. This will be achieved in two levels.

**Learning activity design and editing**. Educators will have the opportunity to structure activities following design thinking steps as described in the section above. It should be noted that the ICT-INOV platform will be designed in a manner that allows flexibility to educators to select the design thinking steps that they will integrate into the activities that they design for their students. For this reason, as discussed above, the platform will not specifically name the design thinking steps but will allow the educator to define them. Once the educator decides which steps she wishes to include in an activity, she can create notes in each step with instructions for the students for its implementation.

**Course structuring services**. Once they have designed the activities, educators will be able to create courses around them with specific learning objectives. A course will be a working area for a specific theme in which students will be able to work in teams in assigned digital workspaces. The teacher will control access to the course through a code. Students will be able to register to the course and team workspace.

Notably, teams may work on the same activity or different ones. This is significant because it allows the educator the highest degree of flexibility in designing the course structure. For example, the educator may wish for all teams to work on the same overarching theme, such as waste management, to demonstrate at the end of the course that it is possible for teams to work on diverse related topics contributing to the addressing of a high level challenge, for example recyclying, cleaning the oceans, discouraging litering in a city and more. On the other

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hand, the educator may assign different topics to teams to allow the class to experience design in different contexts. For example, under the general umbrella of green development, the educator may assign projects on green tourism, green cities, green food production and more.

The educator will also be able to review analytics information on student engagement with the objective of adapting activities to best meet student needs.

**Inspiration material for activity development**. A library of suggested tasks that educators can use when structuring an end-to-end gamified design thinking activity for their students. These will be short exercises that educators can refer to when seeking ideas to mix and match for developing course content. Tasks will promote different steps of the design thinking process, such as empathy, problem discovery, problem statement definition, ideation, prototyping and evaluation. The content will be available for educators registered in the ICT-INOV digital learning platform. As an example, suggested tasks for team building may include a team canvas creation in which team members outline the goals and skills available in the team as well as the working rules or group tasks taking place in or out of the classroom that can only be achieved through collaboration to underscore the importance of team work. For problem discovery, tasks may include a neighborhood walk in the company of different specialists, such as a gardener, a maintenance worker or an engineer, each of whom has a different view point on potential improvements, demonstrating the point of view contept [53]. It may also include shadowing a characteristic user to experience challenges she faces everyday. For ideation, tasks may encourage students to introduce rich ideas and to build on the ideas of each other. For evaluation, tasks may encourage students to categorize ideas in terms of innovation and immediate feasibility, helping them to select a solution for prototyping.

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**Sharing of activities and courses**. ICT-INOV aims to promote the sharing and re-use of content among teachers. This will allow the creation of a community spirit in the teaching community. It will further allow educators to be recognised for their creative work. And finally, it will add value to the generated educational content by allowing others to build on it and to expand it. This will be achieved by enabling educators to make their activities public.

**A library of public complete activities**. A library of complete learning activities will be available. Public activities will not only be visible by other educators; rather, educators will be able to either use them directly in their courses or copy them in their working space and adapt them to their own students' needs, with the option of making the result again public. At least 45 complete activities will be published through the platform.

### 3.3.3 Linking the ICT-INOV learning intervention to the development of desirable innovation skills

The ICT-INOV learning methodology has been designed to develop the skills that students perceive as being important elements of individual and group innovation capacity, as these have emerged from the survey conducted early in the implementation period and described in section *2 Student survey framework* of this report. The skills that students perceived as being most relevant in innovation generation are creative thinking, problem-solving, thinking of of the box, analytical thinking, being imaginative, data gathering and analysis, communication, evaluation and reasoning. These skills are fostered by the ICT-INOV learning methodology as described in the following table.


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| Skill | ICT-INOV activity that supports skill development |
|---|---|
| Creative thinking | **Activity that develops the skill**: Ideation, prototyping.<br><br>**Skill development process**: Ideation and prototyping challenge students to think creatively and out of the box to introduce solutions based on often limited resources. |
| Problem-solving | **Activity that develops the skill**: Problem discovery, prototyping, evaluation.<br><br>**Skill development process**: Problem-solving is in the heart of design thinking activities, which aim at introducing solutions to difficult problems. Students develop problem-solving skills by analyzing the available data that help describe the problem, synthesizing solutions and evaluating how they address the needs of the target group. |
| Thinking out of the box | **Activity that develops the skill**: Ideation.<br><br>**Skill development process**: Ideation challenges students to introduce ideas with an emphasis on bread instead of depth. Activities encourage students to consider different approaches that may lead to a solution to the given problem ranging from practical and directly |

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| | |
|---|---|
| | implementable to solutions that are in the concept stage and require technological maturity not available yet for implementation. |
| Analytical thinking | **Activity that develops the skill**: Problem discovery, problem statement definition, ideation, prototyping, evaluation.<br><br>**Skill development process**: Analytical thinking is a core competency required for performing problem discovery, namely research on the actual parameters of the problem, defining a problem in a way that can lead to solution design, brainstorming for generating diverse ideas towards a solution, creating working prototypes with limited resources and evaluating the effectiveness of prototypes with users. |
| Being imaginative | **Activity that develops the skill**: Problem statement definition, ideation, prototyping.<br><br>**Skill development process**: Imaginative thinking is key in defining a problem statement that allows the generation of a solution. Imagination is in the core of the ideation and brainstorming process. Finally, imaginative thinking is significant in prototyping, particularly when resources |


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| | |
|---|---|
| | are limited. |
| Data gathering | **Activity that develops the skill**: Problem discovery, evaluation.<br><br>**Skill development process**: Problem discovery challenges students to research and information from diverse sources, such as on-line databases and interviews, that accurately describes the problem in focus. Evaluation activities further require data gathering and analysis in relation to the effectiveness of the proposed solution. |
| Communication | **Activity that develops the skill**: Group work, problem discovery, ideation, prototyping, evaluation.<br><br>**Skill development process**: All gamified design thinking steps require group communication. Effective collaboration and building on the contribution of team members can maximize the positive impact of a proposed solution. |
| Evaluation | **Activity that develops the skill**: Problem discovery, valuation.<br><br>**Skill development process**: During problem discovery students must evaluate the validity of information that |

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| | |
|---|---|
| | stems from different sources. During solution evaluation they must determine the degree to which their intervention addresses the needs of the target group. |
| Reasoning | **Activity that develops the skill**: Problem statement definition, prototyping, evaluation.<br>**Skill development process**: Students must reason when introducing a problem statement definition. They must also reason on solution design and in the context of evaluating the effectiveness of their proposed solution with respect to target group needs. |

**Table 2. ICT-INOV gamified design thinking activities that support the development of innovation skills as these have been identified by students in a survey.**

The ICT-INOV survey documented how students perceive innovation. Some of the most popular responses include change, turning ideas into products, mixing new ideas from old, adding value, introducing new perspectives, and capture new value in new ways. The ICT-INOV learning intervention addresses these perceptions as described below.

| **Student perception on what is innovation** | **How ICT-INOV encompasses innovation perceptions** |
|---|---|
| Change | The purpose of the ICT-INOV gamified design thinking methodology aims at introducing change in business and social entrepreneurship contexts that lead to the |


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| | |
|---|---|
| | enrichment of quality of life. |
| Turning ideas to products | ICT-INOV gamified design thinking enables the introduction of workable solutions even for difficult problems when no solution appears to exist at first sight. The focus is on solutions that are implementable and can have a direct and immediate positive impact on target users. |
| Mixing new ideas from old and capturing new value in new ways | The ideation process of the ICT-INOV gamified design thinking approach heavily relies on the integration of ideas suggested by team members and on building on each others contribution towards a workable prototype based on existing resources. |
| Adding value | ICT-INOV gamified design thinking solutions add value by enriching the quality of life of target users. The proposed methodology helps introduce solutions to difficult challenges not yet effectively addressed. |
| Introducing new perspectives | ICT-INOV gamified design thinking encourages students to approach challenges from a different perspective that allows the accurate definition of a problem statement and leads to a solution implemented in a new approach |

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| | |
|---|---|
| | possibly not considered before. |

**Table 3. How ICT-INOV encompasses student perceptions on innovation.**

Finally, the ICT-INOV gamified design thinking methodology is open and inclusive, addressing the needs of students with diverse learning styles as these are described in section *3.2.3 Related pedagogical theories* as described below. Each individual has strong problem-solving skills that can be deployed in the context of team work towards synthesizing effective solutions.

| **Learning style** | **How ICT-INOV addresses learning needs** |
|---|---|
| Converger | The ability of a converger to focus on reasoning and specific problems offers strong benefit to her team in terms of solution deduction and design. |
| Diverger | The strong imaginative ability of a diverger and her interest in people and their needs can contribute to the analysis of characteristic users, problem discovery and the introduction of innovative ideas towards a solution. It can also contribute to effective evaluation of the proposed solution in relation to actual user needs. |
| Assimilator | The focus of an assimilator on theoretical models and abstract concepts can be deployed in problem statement definition and ideation towards generating a rich pool of ideas towards a potential solution. |

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| | |
|---|---|
| Accommodator | The strength of an accommodator on doing things can help his team in the implementation and prototyping stage. His problem-solving capacity can contribute to solution design. |

**Table 4. How ICT-INOV addresses diverse learning styles.**

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## Conclusion and discussion

The ICT-INOV methodological learning framework aims to build the capacity of organizations as well as individual educators to design, structure and deliver learning activities that help build the innovation capacity of students. This high level goal benefits both educational organizations, by supporting the updating of their educational practices for the modern world, and students, by building the theoretical and soft skills demanded by industry and society today.

This goal can only be achieved through a holistic learning intervention that addresses the challenges that educational organizations face towards integration innovation skill development activities into existing curricula: insufficient infrastructures, both physical in the form of labs and digital in the form of educational services, lack of open educational content that can be deployed in learning and educator skill updaring.

The proposed ICT-INOV methodological learning design integrates emerging design thinking and gamification methodologies to introduce an active learning environment in which students and educators are encouraged to bring forward their creativity and to work in teams in problem solving contexts. ICT-INOV supports the development of physical infrastructures, digital learning services, open and reusable educational content and educator capacity building.

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# Annex 1 – Student survey questionnaire

**1. Country** *

(Please, refer to the country where you are studying)

_____

**2. Age** *

□ 18 - 25

□ 26 - 30

□ 30+

**3. Gender** *

□ Male

□ Female

**4. Title of academic study** *

□ Bachelor

□ Master

□ PhD

**5. Major area of study** *

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_____

**6. Year of study** *

□ I have started my first year.

□ I am in the middle of my academic study.

□ I am about to finish.

**7. In your opinion, what does "innovation" mean?** *

- ○ "…the successful conversion of new concepts and knowledge into new products, services, or processes".
- ○ "Innovation is significant positive change."
- ○ "…is the creation and capture of new value in new ways."
- ○ "Innovation is change that creates a new dimension of performance."
- ○ "Innovation transforms the useful seeds of invention into widely adopted solutions valued above every existing solution."
- ○ "Making connections to bring something new to the world."
- ○ Other

**8. If you answer "other", please, describe your idea:**

_____

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**9. Are you engaged in activities for building innovation skills?** *

□ Yes

□ No

**10. If yes, please provide an example.**

_____

**11. What skills do you believe are the most important for innovation?** *

*Please, provide 3 - 5 options.*

□ Analytical thinking

□ Data gathering and analysis

□ Generalisation and abstraction

□ Problem-solving

□ Reasoning

□ Creative thinking

□ Thinking out of the box

□ Collaboration capacity

□ Investigating sources

□ Being imaginative

□ Evaluation of ideas stemming from different sources

□ Communication skills

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□ Time management

□ Other

**12. How important are innovation skills in ICT education?**

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Not at all | ○ | ○ | ○ | ○ | ○ | A lot |

**13. What skills do you believe are the most important for innovation in ICT careers?** *

*Please, provide 3-5 options.*

□ Analytical thinking

□ Data gathering and analysis

□ Generalisation and abstraction

□ Problem-solving

□ Reasoning

□ Creative thinking

□ Thinking out of the box

□ Collaboration capacity

□ Investigating sources

□ Being imaginative

□ Evaluation of ideas stemming from different sources

□ Communication skills



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□ Time management

□ Other

**14. How important are innovation skills in ICT careers?** *

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Not at all | ○ | ○ | ○ | ○ | ○ | A lot |

**15. How important are innovation skills for addressing industry and society needs?**

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Not at all | ○ | ○ | ○ | ○ | ○ | A lot |

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**16. What of the following emerging learning design approaches are you familiar with?**

*"Learning design" refers to the framework that supports learning experiences.* *

| | 1 (Not at all) | 2 | 3 | 4 | 5 (A lot) |
|---|---|---|---|---|---|
| Problem—based learning | ○ | ○ | ○ | ○ | ○ |
| Active learning | ○ | ○ | ○ | ○ | ○ |
| Experiential learning | ○ | ○ | ○ | ○ | ○ |
| Design thinking | ○ | ○ | ○ | ○ | ○ |
| Gamification in learning | ○ | ○ | ○ | ○ | ○ |

**17. Please provide an example, if applicable.**

_____

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**18. Which of the following methods do you use in your practice?** *

| | 1 (Not at all) | 2 | 3 | 4 | 5 (A lot) |
|---|---|---|---|---|---|
| Problem—based learning | ○ | ○ | ○ | ○ | ○ |
| Active learning | ○ | ○ | ○ | ○ | ○ |
| Experiential learning | ○ | ○ | ○ | ○ | ○ |
| Design thinking | ○ | ○ | ○ | ○ | ○ |
| Gamification in learning | ○ | ○ | ○ | ○ | ○ |

**19. In your opinion, which of these skills do you currently work on through curricula activities?** *

*Please, provide maximum 4 options.*

□ Analytical thinking

□ Problem-solving

□ Reasoning

□ Creative thinking

□ Thinking out of the box

□ Collaboration capacity

□ Investigating sources

□ Being imaginative

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□ Evaluation of ideas stemming from different sources

□ Communication skills

□ Execution skills

□ Design capacity

□ Manipulation

□ Assembling skills

**20. Can digital technology promote the development of innovation skills?** *

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Not at all | ○ | ○ | ○ | ○ | ○ | A lot |



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**21. Which digital tools and services could help build innovation skills?** *

□ Online learning systems

□ MOOCs

□ Simulations and games

□ Online communities

□ Online collaboration systems

□ Mobile apps

**22. Please provide an example of building innovation skills in your curricula.** *

_____

**23. Please comment on the importance of innovation skills in the 21st century.** *

_____



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# Annex 2 – Content analysis

**Q5 – Major area of study:**

| | |
|---|---|
| **ICT** | ICT<br>Computer science<br>Information technology<br>Network security<br>Data science<br>Applied Mathematics for Data Science and Finance<br>Digital Game Design<br>Human-Computer Interaction<br>Machine learning<br>Software programming<br>Cybersecurity<br>Computer system and networking<br>Artificial intelligence<br>Software Development |

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| | |
|---|---|
| | Computing<br>Informatics<br>Graphic design<br>Graphical Systems and Multimedia |
| **Engineering** | Software engineering<br>Engineering<br>Physics Engineering<br>Electrical Engineering<br>Electrical and Computer Engineering<br>Requirement Engineering<br>Security and Safety of Critical Software<br>Mechanical Engineering<br>Electrical Power Engineering<br>Civil Engineering<br>Network Engineering<br>Energy<br>Computer Engineering |


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| | |
|---|---|
| | Energy management<br>Energy Storage<br>Materials- Corrosion<br>Fluid Dynamic |
| **Social Studies** | Social Studies<br>Psychology<br>Communication<br>Sociology<br>Investigation and Security Sciences<br>Educational Technology<br>Literature<br>Law<br>International relations |
| **Business** | Economics and Informatics<br>Economics<br>Quantitative Finance<br>Accounting |

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| | |
|---|---|
| | Entrepreneurship and Venture Management<br>Marketing and Digital Communication<br>Business Economics<br>Business |
| **Science** | Science<br>Natural Science<br>Physics<br>Industrial Science<br>Medicine<br>Medical Biotechnologies |

**Q8 – In your opinion, what does "innovation" mean?**

**Other, describe:**

- Innovation is converting idea into new product. For example, the idea of solar energy gen into solar panels.
- All of the previous answer, idea implementation on current product/service or to create new ones.
- Innovation is a spark; it's a beam of light that illuminates an old method or creates a new one by mixing the existent ones.


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- All of the above definitions make sense.
- Innovation is something that has value to commercialise or improvise.
- Something new derived from a previous occurrence, majorly applicable items but also newfound theories.
- Innovation is something you have done not for yourself but for people all over the world.
- Innovation is proposing a new perspective, regardless of its success, in an already existing industry.
- Conversion of old idea into a new and better idea.
- Almost all of them
- Innovation is a change in existing fields of knowledge and practices, adopting new techniques, changing existing ways of working, often using new technologies. Its purpose is to bring positive change, but it doesn't always work out that way. Each positive change can have its dark side. Innovation can also lead to alienation, as old, less efficient ways sometimes have positive side effects. At the same time, it can get rid of some nasty old practices that are bringing everybody down.

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**Q10 – Are you engaged in activities for building innovation skills?**

**Provide an example:**

| Type of activity | Example |
|---|---|
| **New product realisation** | • Produce new type of plastic for commercial use.<br>• Design an innovative dish collector trolley<br>• Make learning game |
| **Implementation of new solutions** | • Virtual Design Sprints are one of the ways<br>• I've engaged in innovating existing solutions.<br>• I help start-ups by creative ideas to improve their products.<br>• New engagement for renewable<br>• Financing solutions |
| **Participation in events, seminar,** contests focused on innovation | • Presentation competition<br>• Participated in several innovation contests<br>• Robotic & STEM Competitions<br>• Project work in each semester<br>• Robotics club<br>• FYP project |

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| | |
|---|---|
| **Learning new skills** | • Programming, Machine learning, Data science<br>• I am working in Solar field<br>• Learning new skills in research, testing automation<br>• I try to solve problem usually related to programming by myself<br>• Projects in our master course<br>• Through my studies at university, I am slowly gaining the skillset required to build new and never seen before technologies.<br>• I am taking Research Methodology class that emphasise on having structures in developing ideas and designing the research<br>• By conducting Research about different aspects<br>• Currently working on my communication skills.<br>• I think that what we do in the course is innovative<br>• Critical thinking, analysing<br>• Not sure but I guess learning in general<br>• PBL, analytical and critical thinking, collaboration and communication |

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| | |
|---|---|
| | • Building hobby projects |
| **Innovative teaching methodology applications** | • Innovative teaching methods<br>• Course assignments involve innovation<br>• My PhD is an example of innovation, creating new techniques and algorithms<br>• Art and musical ideas combined with electronics<br>• Creating software for education<br>• We have to come up with new ideas for the practical courses.<br>• AI assistant for MOOC podcasts and AR gamification for historic sites. |
| **Involvement in innovative processes** | • Interaction design activities<br>• Making ideas come to live<br>• Doing research in the field of software engineering<br>• Neural Link. Regarding neural transmission in e-medium<br>• Battery energy storage optimisation and decarbonisation<br>• Create new way to improvise a certain process<br>• For past few years, I have been honing my skills to find new |

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| | |
|---|---|
| | things and different ways of achieving existing things<br>• Sustainable energy production |

**Q17 – What of the following emerging learning design approaches are you familiar with? Provide an example, if applicable.**

- I usually use some computer's programs in order to solve some of my problems (for example, I use a program that is really good for making maps which is necessary for my studies).
- Using games in some courses.
- Using a gamified virtual meeting space for a student.
- Using design thinking to plan our prototype creation.
- Solving problems by doing, do the experimenting.
- Making applications that would have a real-world use case.
- Using case study evaluation, empirical studies and active learning games.
- Using game elements to increase student engagement and adherence to online learning.
- My team and I used problem-based learning in the entrepreneurship course. We define the issues and the theme of our assignment, investigate solutions and present the chosen solution.
- As we are computer science students, we are taught problem-solving skills and we always focus on staying relevant and up to date with the latest technologies out there.


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- A program I had to make as a project that needed pre-design and to do that, I tried to present it to myself as a structured game.
- Like playing resource management games can help you manage the resources process.
- Learn programming by games.
- Raising the level of learning is the basis of innovation.
- I used PBL a lot in my MSC.
- We do a lot of projects in our courses.
- Trying to learn about artificial intelligence, BCI and such innovations. Simulation and console. Making of assignments.
- I can solve problems of lab tasks I get. For example, a customer needs a program that calculates his/her grocery bill. I have learning skills like that only.
- Experience in Design thinking. Web development like other programs designing.
- I can solve problems of lab tasks I get. For example, a customer needs a program that calculates his/her grocery bill.
- Design projects, hands-on projects, Socratic method, real-world problem analysis.
- Learning by building projects.
- We do active hands-on works.
- Interactive audio for MOOC podcasts instead of the usual visual MOOC content

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