PRELIMINAR TEACHING UNIT

Introduction and methodology

DEVELOPING AN ARTIFICIAL INTELLIGENCE
CURRICULUM ADAPTED TO
EUROPEAN HIGH SCHOOLS

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1. Curriculum scope

The current Artificial Intelligence (AI) curriculum has been developed for students from 14 to 17 years old, with some previous basic knowledge of technology, mathematics and programming, as it will be clearly defined in the following sections. It will cover a two-year period previous to their incorporation to tertiary education.

This curriculum is focused on technology or science students (not arts or humanities), mainly because it requires a mathematical background to be properly followed. But, at the same time, it must be useful in a science general scope, that is, it will be applied to students which can specialize in basic sciences, engineering or health.

The main objective is to provide initial training in AI so students gain basic knowledge about how AI systems operate. To achieve it, the curriculum has been organized in teaching units (TU), each of them presenting a real-world problem that must be solved by the students in a project-based learning approach. The teaching approach followed here is that of **learning by doing**, so students will acquire the knowledge by solving the activities associated to each TU in a pro-active fashion.

The description of the TUs and the challenges included in this curriculum have been implemented ***for the teacher***, that is, the material is not directly for the student, but for the teacher to use it to structure and organize their classes. They can be used directly, or simply as a guide for the teacher to adapt to the particularities of each group. Consequently, the teacher must review each TU before the class, performing all the activities that have been created.

2. Artificial Intelligence background

A great technological revolution is to come in the next few years based on the widespread presence of intelligent computational systems in our society. Autonomous vehicles, service and assistance robots or automated buildings, among others, will be part of our daily lives creating a global network of interconnected devices that will surround us. The main characteristic of these embedded systems will be their "intelligence", understood as their flexibility and adaptability to deal with many different situations in an autonomous way, even learning from their own experience.

We can find different definitions of what AI is, and all of them are related with the same idea: it is a field of computer science focused in providing computational systems with the capability of solving problems as humans would do, that is, based on cognition. More specifically, AI provides a computational-based artificial system (not biological) with the capability of solving problems autonomously, without human intervention. To do it, the AI system is able to learn from experience, to adapt to new situations, and to reason about the best way to solve a problem.

Fig. 1. Basic components of an AI ecosystem

To define what an AI ecosystem is composed of, we can consider the diagram shown in Fig. 1, which contains 4 main blocks and their relations. There must always exist an *environment*, real or virtual, where the *AI system* operates. The *AI ecosystem* includes a *Sensing* stage, where the sensors are used to obtain information from the environment. In addition, it includes an *Acting* stage, that is, the environment can be modified to some extent through the actions applied by the *AI system*. With the information coming from the sensors, the *AI system* has to select the most appropriate action (or actions) it must execute in the environment to fulfill its goals. This action modifies the environment, then new sensing values must be obtained to perceive such changes, and the *AI system* has new information regarding the adequacy of such action to achieve its goals. This process continues over time, so the *AI system* can learn from its experience in order to improve the action selection. If we change the AI system by a human being, this ecosystem is still applicable, because this interaction is exactly what we are doing in our everyday life.

The complexity of the AI system illustrated in Fig. 1 can vary wildly, and this establishes the cognition level it can achieve and, consequently, it limits the optimality of the decisions that can be executed. Fig. 2 contains a schematic of the main elements that compose an AI system from an engineering point of view:

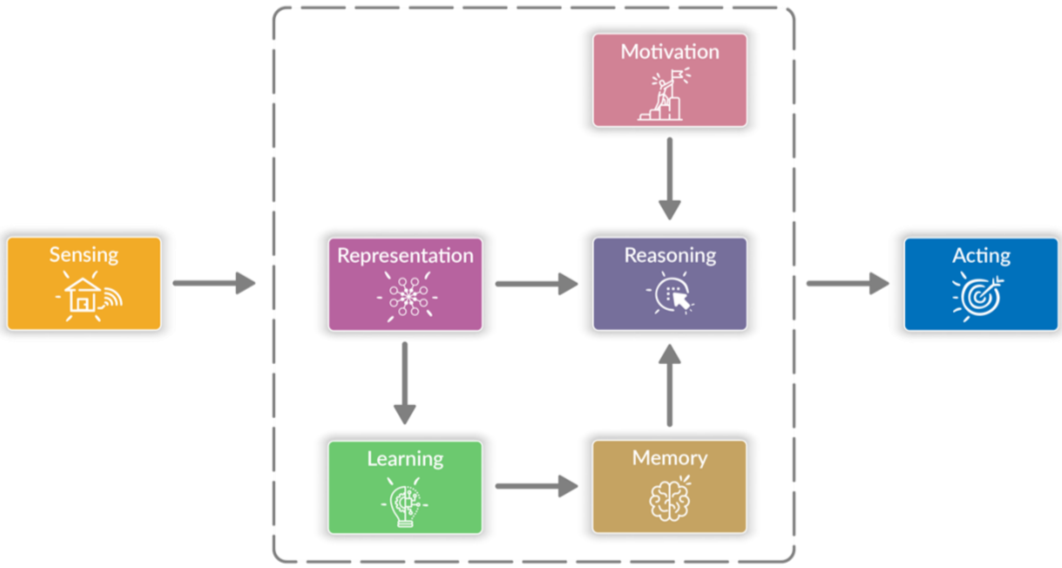


Fig. 2. Main elements of an AI system

We can see that it is composed by 5 blocks or sub-systems, linked with Sensing and Acting as explained above. These 5 blocks are the following:

1. *Motivation*: the AI system must have some type of motivation to operate, that is, the system must fulfill some goal. The motivation can be imposed by the designer or it can be learnt by the system, which implies a higher level of intelligence.
2. *Representation*: the information coming from the sensors must be stored in the computational system under some type of representation, which is very important in order to simplify the remaining processes.
3. *Learning*: every AI system must learn from experience. This feature is very relevant, because it provides the property of adapting to new situations, and consequently, being really autonomous.
4. *Reasoning*: the system must select the action to be applied in the environment following some type of decision process, from a very simple one, reactive, to a very complex, using internal models, planning, or others.
5. *Memory*: it is mandatory that an AI system has different types of memory elements to store the models that are learnt, the representation, and other important data that could be useful in the future to avoid re-learning.

Each of the blocks that are displayed in Fig. 2 must be present in the implementation of a complete AI system, although their complexity level can go from very simple to very complex, leading to a more or less intelligent response.

To illustrate how a real AI system could implement these blocks, we could think of an intelligent car, that is, and autonomous vehicle. This car is endowed with different *sensors* like cameras, lidar, GPS, microphone, tactile screen, etc., and *actuators* like motors on the wheels, a speaker, an LCD screen, among others. The objective of this intelligent car is, for instance, to drive safely towards a predefined location. The information obtained by the car from the camera and the GPS could be used in the *representation* block to position the car in a map and to move safely. This representation is used by the *reasoning* block in order to find the shortest path to the target location, which sends the appropriate actions to the motor wheels. In this example, we could think about a *learning* system that analyzes the traffic in different days, and predicts a faster path to the target location considering the past experience. This learnt model should be stored in a *memory* in order to be reused the next time a similar situation is faced. So, as we can see, all the blocks shown in Fig. 2 are very relevant in this intelligent operation.

3. Artificial Intelligence topics for pre-university education

One of the most important and complex parts of this curriculum is to establish which specific topics of AI must be covered in pre-university education. Keeping in mind the blocks displayed in Fig. 2, we propose 8 main topics that should be addressed in this curriculum:

1. Perception
2. Actuation
3. Representation
4. Learning
5. Reasoning
6. Collective Intelligence
7. Motivation
8. Sustainability, ethics and legal aspects of AI

As it can be seen, most of the implementation blocks displayed in Fig. 2 correspond to specific topics that will be studied in the curriculum, although new topics like collective intelligence and sustainability must be treated independently.

4. Teaching organization and methodology

The AI teaching approach that will be followed here is **focused on embedded intelligence**, that is, programming real-world devices that interact with real environments. This requires relying on some specific hardware elements in order to implement the teaching material. To this end, in order to follow the most general approach possible, we have established as a **key premise in the project using the student's mobile phone (Smartphone)** as the central technological element for all educational material to be developed.

Current smartphones have the technological level required for AI teaching in terms of sensors, actuators, computing power and communications; and they will have it in the future because they are continuously being updated. They can be considered as general public devices, with a very similar presence in all the European states. This is very important for this proposal, because a large majority of high school students have their own Smartphone, so they can use it for learning. This significantly reduces the cost of introducing this discipline, and equalizes regions with different economic capacity.

4.1 STEAM

The present curriculum follows a STEAM methodology (Science, Technology, Engineering, Arts, Mathematics), which focuses on the integrated learning of different technical and scientific concepts through an engineering approach. In addition, an artistic perspective is included in this approach that promotes creativity, originality and generation of new ideas in an autonomous way. Each TU will present a challenge or project that the students must solve in a creative and practical way, organized in teams or groups. This approach is based on a totally pro-active learning and through the solution of problems in the real world (learning by doing), according to the eminently practical approach of our approach to AI. The theoretical concepts necessary to solve each challenge will normally be from different technical and artistic disciplines, and will be worked in an integrated manner.

AI is a technological field that fits 100% in the STEAM methodology, since it requires knowledge from different disciplines to solve problems, such as physics, mathematics, programming or design, where creative solutions are a nuclear element. At the organizational level of the TU, the core part of the present curriculum is based on the teaching of the main 8 AI concepts defined in section 2, which are introduced in a logical order from least to greatest difficulty. Paired with them, knowledge of the complementary disciplines will be reinforced. These reinforcement concepts have been organized into 3 major blocks: logic (programming), mathematics and science (physics, chemistry, biology). The artistic skills will be covered in the design and manufacture of accessories and additional elements for the TUs, in the creativity when proposing realistic AI solutions, and directly in the use of Smartphone's capabilities to carry out projects related to artistic fields, like music or drawing.

4.2 Required resources

For the realization of the TUs of this curriculum, it will be necessary:

1. One smartphone per group.
2. One computer, laptop or desktop, equipped with wi-fi connection, per group.
3. One wi-fi network to which the smartphone and the computer can be connected.

In addition, in some TUs, additional hardware will be required:

1. One Robobo robot per group
2. IoT accessories (see each TU for a specific description)

Finally, within the STEAM methodology, in most of the TUs it will be necessary to design and build some accessory, or use some extra element. These elements will be described in each of the TU.

4.3 Pre-requisites

All the students that are enrolled in this AI training must have previous formation in the following topics:

- **Programming**: students must have experience in block-based programming. They should have learned the following basic topics:
  1. Conditionals
  2. Loops
  3. Functions (custom blocks)
  4. Variables

  Recommendation: if students do not have previous experience in programming, we encourage teachers to carry out some courses available at code.org. There are three courses that start from a basic level (course D) to a higher level (course F). It is recommended that all students start from the first lesson of course F and if they are able to do it without any problem continue with it without doing the previous ones (D and E). If, on the other hand, the level of that lesson is high for them, they must move on to the first lesson of course E and follow the same steps: if they overcome it without difficulty, continue with that course and then take the F and if the level is too high, start with course D and then do the E and F.

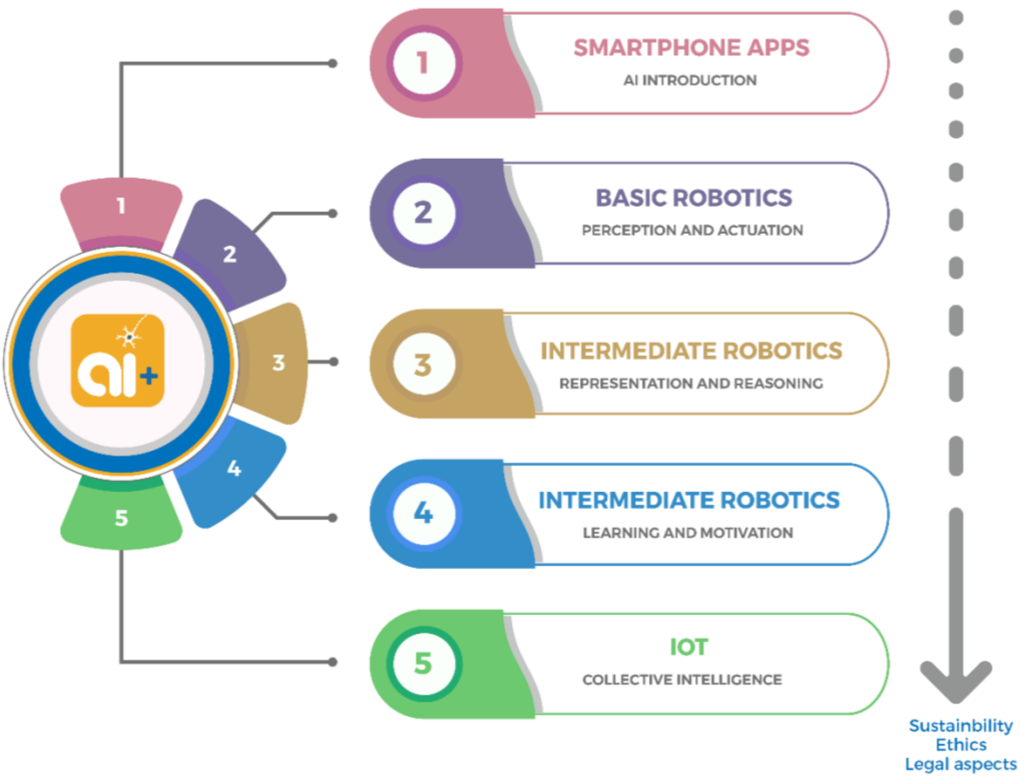
- **Mathematics**: to start following this curriculum, the students should have knowledge about the following mathematics topics:
  - Integer numbers
  - Angles
  - Real numbers
  - Basic algebra
  - The cartesian plane
  - Geometry and basic figures
- **Physics**: regarding physics, students should have basic knowledge of:

- Distance measurements
- Time measurements
- Linear motion
- Basic magnitudes (energy, force, mass, etc)

Other scientific or technical topics that could be required for specific TUs will be detailed on them, always considering that they will be adapted to the student's range of ages.

4.4 Curriculum organization

The AI curriculum has been structured in 5 levels of incremental complexity, which correspond to 3 application fields in AI, smartphone apps, robotics and Internet of Things (IoT). Although many other application domains could have been selected, these are very representative of current AI domain, and all of them can be developed using an Smartphone:



Each of these 5 levels contains a different number of TUs, which cover the 8 topics established in section 2. The specific organization of the curriculum is the following:

	Level	Unit	Topics	Tool	Hours	Weeks
FIRST YEAR	Intelligent Smartphone Apps	1	AI Introduction	App Inventor	2	1
		2	Perception and Actuation (basics)		4	2
		3	Representation and reasoning (basics)		4	2
		4	Learning (basics)		4	2
		5	Collective Intelligent (basics)		4	2
		6	Sustainability, ethics and legal aspects (basics)		2	1
				Total	20	10
	Basic Robotics	7	AI Introduction	Robobo	6	3
		8	Perception and Actuation (basics)		6	3
		9	Representation and reasoning (basics)		8	4
		10	Learning (basics)		8	4
				Total	28	14
	Intermediate Robotics	11	Representation	Robobo	4	2
		12			4	2
		13	Reasoning		6	3
		14			6	3
				Total	20	10
SECOND YEAR	Intermediate Robotics	15	Learning	Robobo	4	2
		16			4	2
		17			4	2
		18	Motivation		8	4
		19			8	4
				Total	28	14
	Internet of Things	20	Collective Intelligent	Robobo	6	3
		21			6	3
		22			6	3
		23			6	3
		24			8	4
		25			8	4
				Total	36	20

It covers two academic courses, each of them of 34 weeks, with 2 hours of teaching per week associated to this subject. The curriculum has been divided into 25 TUs, implying a variable number of attendance hours. The 8 topics established in section 2 are studied throughout the TUs in an incremental way, so the last ones, although focused in Collective Intelligence, will require concepts of all the previous ones. SEL (Sustainability, Ethics and Legal aspects), will be treated in all the TUs, so we have decided not to include it in any specific part of the previous table.

4.5 Teaching unit organization

Each of the teaching units that make up this curriculum contains the same 10 sections:

1. Introduction
2. Context
3. Learning objectives
4. Contents
5. Evaluation

6. Temporary organization
7. Required resources
8. Bibliography
9. Challenge / Project
10. Complementary activities

In addition to these specific sections, there are a series of methodological aspects that are common to all of them and that are detailed in the following below sub-sections.

4.6 Key competences

In the different TUs, the following key competences will be worked on:

- ***Linguistic communication***, in the search for information and in the exhibition of projects.
- ***Mathematical competence and basic competences in science and technology***, acquired in the resolution of problems through numbers and operations, and in the necessary critical judgment and logical thinking that the scientific method, in which the challenges are based, requires.
- ***Digital competence***, with the use of the computer, the smartphone, the robot, and other hardware for IoT.
- ***Learning to learn,*** in the management of time and work of the project-based learning strategy.
- ***Social and civic competences***, in the collaboration when working as a team with the respect for different social classes.
- ***Sense of initiative and enterprising spirit***, when carrying out the research work that generates initiatives and creativity.
- ***Awareness and cultural expressions***, to develop artistic expression, present in the development of materials that will serve as support in the achievement of the challenges, and also promoting the generation of new ideas and creativity.

4.7 Learning goals

The specific learning goals to be achieved with the present curriculum are the following:

- Approaching with autonomy and creativity, individually and in groups, independent AI problems working in an orderly and methodical way to study the problem, collect and select information from different sources.

- Having sufficient technical skills and knowledge for the analysis, intervention, design, development and handling of materials, objects and technological systems in a safe and accurate manner.
- Expressing and communicating ideas and technical solutions, as well as explore their viability and scope using the appropriate technological means, graphic resources, symbology and vocabulary.
- Adopting favorable attitudes to solve technical problems, developing interest and curiosity towards technological activity, critically analyzing and evaluating research and technological development and its influence on society, the environment, health and personal well-being and collective.
- Acting in a dialoguing, flexible and responsible manner in teamwork, in the search for solutions, in decision-making and in the execution of tasks entrusted with an attitude of respect, cooperation, tolerance and solidarity.
- Developing the creative and artistic capacity, individual thinking, original, but adequate to the problem to be solved.

4.8 Class organization

The class organization is based on project-based learning (PBL) methodology with cooperative learning. It is an active methodology, where the student directs his own learning, which will be as autonomous as possible. The teacher will act as counselor, mediator or guide towards solving the problem. With this method, students will reinforce teamwork, improve oral presentations, encourage critical thinking and awaken greater interest in the activities proposed, increasing motivation and creativity.

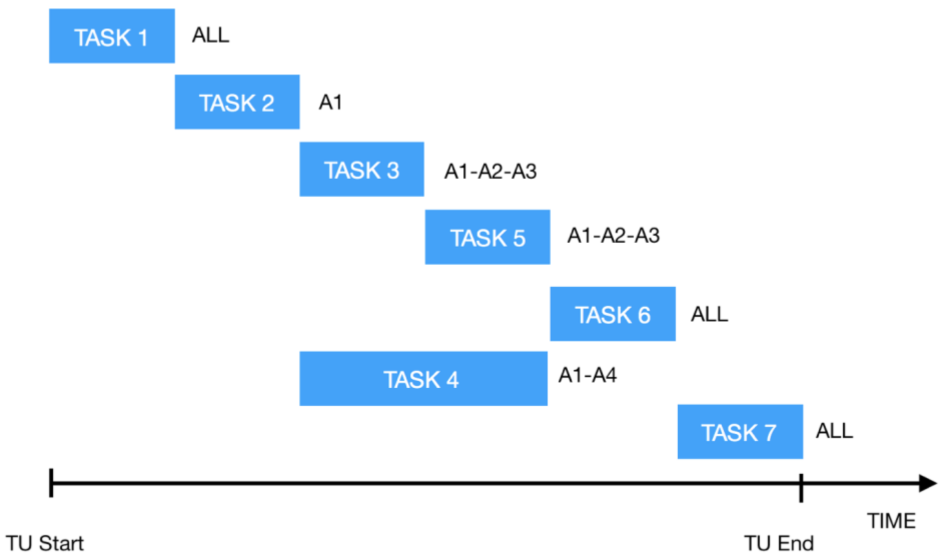
In particular, to carry out the TUs, we propose to organize the class in groups of 4 students maximum. Considering that the members of the group are denoted by A1, A2, A3 and A4, the following organization is proposed in 3 roles:

1. *Time Manager (A1):* Controls that the different stages of the TU are carried out in an orderly manner and on time according to the time frames commented by the teacher. He/She is the group manager and is responsible for speaking with the teacher if necessary. He/She is in charge of documenting the steps of the work, in writing, with images, with video …
2. *Programmer (A2, A3):* They make the flow diagram (to the teacher's consideration), they do the mathematical and logical calculations necessary for the program to work. Once the program design is finished, they start programming the Smartphone and verify that it works in reality with the help of the hardware manager.
3. *Hardware Manager (A4):* He/she ensures that the hardware is ready to be programmed. That is, he/she must ensure that the smartphone, robot, or the IoT devices that will be

used in the TU, and the computer, are loaded and operative, and they are configured with the program. He/She is also responsible for preparing the testing environment and getting the necessary accessories to carry out the activities.

As it will be explained later in detail, each TU has a global objective that could be tackled jointly by the students, but in this curriculum it has been decided to prioritize this process, and each TU is organized in activities of increasing complexity that guide the student in a simpler and more orderly way towards the realization of said objective. The previous division in roles must be maintained throughout the TU, and it must change between TUs following a rotation pattern, so at the end of the course, every student has been in every role approximately the same number of times.

As a typical organization scheme in PBL, the division in roles could be temporarily organized in the following tasks (the duration of the tasks is indicative):



- TASK 1. Searching for information:
  - *Objective*: students should look for the necessary information in the bibliography, internet or by asking the teacher.
  - *Responsible*: all students (A1, A2, A3, A4).
- TASK 2. Sharing and distribution of work
  - *Objective*: the time manager must organize the work among the members of the team, setting deadlines and objectives
  - *Responsible*: time manager (A1).
- TASK 3. Program design:
  - *Objective*: the programmers carry out the design of the program prior to its coding.
  - *Responsible*: programmers (A2 and A3) and time manager (A1).
- TASK 4. Preparation of the testing environment:

    - *Objective*: the hardware manager must prepare the test environment, the accessories and the rest of the necessary material to be able to carry out the project.
    - *Responsible*: hardware manager (A4) and time manager (A1).
- TASK 5. Programming:
    - *Objective*: the programmers carry out the program in the language established by the teacher for that TU.
    - *Responsible*: programmers (A2 and A3) and time manager (A1).
- TASK 6. Program tests and adjustments:
    - *Objective*: the programmers test the program in the environment created by the hardware manager and adjust it until it works correctly.
    - *Responsible*: all students (A1, A2, A3, A4).
- TASK 7. Presentation of the project results:
    - *Objective*: to show the teacher, and the rest of the class, the achieved result in practical terms
    - *Responsible*: all students (A1, A2, A3, A4).

In the case of organizing the groups with a different number of members, the teacher is responsible of distributing the 3 main roles between them. When the group is made up of 2 students, one has the programmer role, and the other the Time and Hardware Manager roles. If students require to modify roles or to reinforce some of them during the TU development, it should be approved by the teacher.

4.9 Evaluation

To evaluate the TU comprehension by the students, we must focus the attention in two main aspects:

1. *The correct functioning of the program:* as every TU is based on a challenge/problem that must be solved, students may focus their efforts in the reliability of the program they submit. It is a basic skill in PBL methodology, the final result must be tested and it must work correctly.
2. *The understanding of the AI concepts of the TU*: apart from achieving a reliable solution to the challenge, students must learn the AI concepts behind it, so they can extrapolate them to other problems.

As a consequence, three main evaluation methodologies are proposed in the scope of this curriculum:

1. *Final test of the program:* at the end of the TU, each group must show the operation of the program in the real world. The teacher must perform **a program check**, reviewing if all the expected features of the program have been achieved, and if it solves the problem with reliability. In every TU of this curriculum, there is a section devoted to the

evaluation, with specific features that must be controlled. In addition, the **students must submit the programming code of their solution**, so the teacher could test it if required. As this is not a programming curriculum, the evaluation emphasis will not be on the code quality, but in its functioning.

2. *Final test of theoretical concepts*: at the end of each TU, the **students must fill a short survey** that will focus in the main AI concepts treated during it. This survey will be included in the evaluation section of every TU.
3. *Ongoing work during the TU:* apart from the final result of the TU, it is important to evaluate the "path" followed by the students during the TU completion. This is in accordance with the role distribution we propose, because it is important to evaluate the participation of each student in the completion of the challenge. To this end, we propose to use **individual rubrics that the teacher must fill every week**. They will be specified in each TU, but in general terms, these are the main skills to consider:

Level (score) / Aspects to be evaluated	Expert (4)	Competent (3)	Partially competent (2)	Not yet competent (1)
Adequate selection of information: appropriate sources and capacity for synthesis				
Time management				
Design and construction of the solution: ability to understand the objective				
Technical knowledge				
Creativity				
Attitude: active participation				
Problem solving: practical ability				

As the students advance in the curriculum, the TUs become richer and longer, implying a larger number of activities. From the PBL perspective, they are suitable for developing a final dissemination work by students where they formalize the steps followed to achieve the goal, the problems encountered, and the solutions provided. In such TUs, we will recommend teachers to carry out different activities in the different groups. For instance, one group could carry out an **oral presentation**, other could **make a video**, creating a **podcast**, a **blog** entry, and so on.

Summarizing, each TU contains a section with details about its specific evaluation, although all of them will be based on 5 items with the following percentage in the final grade:

1. The check of the proper program functioning (at the end of the TU) – 50%
2. The submission of the programming code (at the end of the TU) – evaluated in the previous item
3. The filling of a survey with theoretical contents (at the end of the TU) – 30%
4. The filling of individual rubrics (every week) – 20%
5. *Optional*: a dissemination work (at the end of the TU)