Applying Lean to Improve Software Project Management Education

Maria Monserrat, Antonia Mas, Antoni-Lluís Mesquida Calafat, and Paul Clarke

***Abstract*—This article describes how different Lean principles and techniques have been adapted and applied to identify, analyze, and improve the value chain of a Software Project Management module in a computer science curriculum. This research is part of an initiative to improve the processes related to higher education teaching management, at a university, with the main goal of maximizing the value that is provided to students when taking a module. To represent and visualize the whole value chain of the module, the value stream mapping Lean management tool has been used. The essential module activities and the necessary elements to teach each one of these activities, from the first session to the final mark, were detected, collected, and represented using diagrams. The value chain analysis and review were performed by applying Lean principles and techniques. This article details several improvements to be applied to the module to eliminate the waste that did not add value to students.**

***Index Terms*—Engineering education, Lean in higher education, Lean principles and techniques, value chain, waste removal.**

I. Introduction

ONE of the main challenges for a lecturer is to get students interested and motivated in the content to be taught. If the topic is already attractive in itself, it seems that getting students involved can be easier than in other modules that are not so interesting at first. However, in both cases, the lecturer must try to find the best mechanisms to capture students' attention, facilitate their learning, and prepare them to apply this knowledge to their future work [1], [2].

Currently, it can be as or more difficult for a lecturer at a higher education institution (HEI) to find teaching methods adapted to the expectations of today's students than preparing the contents to be transmitted to them: knowledge, techniques, and tools related to the discipline under study.

Student-centered learning has provoked some changes in the organization of teaching at different levels, such as the identification of the most convenient in-class strategies, at-home activities, or the definition of assessment tasks.

For this reason, lecturers need to find and apply new approaches that allow a continuous improvement, from as many perspectives as possible, of the teaching process of a university module, to help the future professional development of the students [1]. In this context, a new challenge could be to improve that learning process by applying Lean principles.

The term Lean was used for the first time as part of a study from MIT's International Motor Vehicle Program [2], related to the goal of assessing the range of productivity performance in the automobile industry around the world. Lean management philosophy, also known as Lean Thinking, emerged from the Japanese automobile industry, the Toyota Production System, as a way to improve production systems by removing waste [3]. Lean Thinking is defined as an operational strategy of excellence that allows people and organizations to change to improve [4]. Lean Thinking provides tools and techniques to detect and eliminate all the wastes that do not add value, from the perspective of what is provided to the end customer. The Lean philosophy is based on five Lean principles that are applied with the general goal of improving the current way of working. One of the principles is based on understanding what value is and what activities and resources are necessary to create that value. The main focus is to remove the steps from processes that are not necessary and do not add any value for the customer [5].

Womack and Jones [6] state that the fundamental ideas of Lean production are universal and applicable anywhere by anyone. Since the publication of [4], the term Lean has spread to different business sectors other than manufacturing and production, from which the Lean philosophy emerged. Lean principles have been applied in health [7], construction [8], service [9], [10], software development, among other sectors. However, according to Sremcev et al. [11], very few studies showed the application of Lean tools and their benefits to the teaching and learning process in higher education.

The application of Lean principles in education may offer several advantages to students and lecturers. Adapting and applying Lean Development principles and techniques to the Software Project Management module in a computer science curriculum represents a real case of applying the concepts taught in the module. This could allow students to understand the

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versatility of the Lean principles and encourage them to apply these techniques in software development companies where they will work as software engineers in the near future.

This research is part of an initiative for improving a Software Project Management module in computer science that started in 2015. In [12], wide research to engage computer science students toward Software Project Management is presented. Two empirical studies were conducted. The first one, based on grounded theory research, took place during the academic years 2015–16 and 2016–17 and was carried out to detect the reasons that influence students to undervalue the Software Project Management course. The obtained findings allowed for the introduction of some improvements in a course redesign. The identified contingencies were applied during the academic years 2017–18 and 2018–19, and in the second study, the student's satisfaction level regarding the new course design was analyzed.

In this article, the main objective has been to consider the perspective of students, by analyzing the activities that provide value to the students of a Software Project Management module. More concretely, the goals of this article are as follows.

1) To describe how some of the Lean principles and techniques have been adapted and applied to identify and analyze the value chain of the "Project Management"module, in the degree in computer science of the University of the Balearic Islands.
2) To identify all the elements that do not provide value to the students and to suggest some improvements to eliminate this waste.

From a managerial point of view, this article can be useful for people with different profiles. The process that is described in this article to analyze and improve the Software Project Management module could be helpful. By adapting and applying this process, any other educational module could be improved, thus providing more value to students. Furthermore, this research could make the students aware of the benefits that Lean principles could bring to software development companies. It can motivate them to apply these Lean techniques when they start working as software engineers. This work could also introduce Lean techniques to software development companies that are not familiar with it. The Lean Software Development principles can be useful for these companies to identify and remove waste and improve their processes. This, in turn, can add more value to their customers.

This article is structured as follows. Section II provides related work and background to the application of Lean principles and techniques in higher education. In Section III, the authors present the improvement cycle used in the study, which is composed of three sequential phases. The first phase, described in Section IV, consists in identifying and representing the value chain of the Project Management module, from the perspective of students. In Section V, all the activities and resources that are part of this value chain are analyzed in depth. Section VI collects the set of improvements that should be applied to make changes in the value chain to eliminate identified wastes. Section VII contains the indicators that will be used to evaluate the improvements. Finally, conclusions and future work are discussed in Section VIII.

II. Related Research

Since the Lean principles appeared, there have been numerous initiatives around the world related to the implementation of these principles in higher education, dedicated to the improvement of both academic activities and administrative or management tasks. From an academic point of view, we find experiences related to the improvement of the organization, preparation, and teaching of a module, as well as with the improvement of the perception and experience of students when taking the module. From an administrative or management point of view, the studies carried out have been aimed at streamlining procedures and increasing the value of the services of the different members of the university community, not only of the students.

Balzer et al. [13] presented a review and perspective on Lean in HEIs. Their work has identified case-based examples of organizational improvements that have benefitted academic and administrative operations. The authors point out that the main areas where Lean has been applied in high education institutions so far are: student administration procedures, redesigning or improving teaching modules, curriculums, researchers' workspaces, student libraries, and other educational facilities. However, according to them, evidenced-based conclusions of the overall impact and effectiveness of Lean in HEIs initiatives are missing from the current body of literature.

The benefits that modern Lean enterprises may have of properly educated and qualified engineers and how the application of Lean tools and principles can improve the educational system is investigated by Vukadinovic et al. [14]. The authors conclude that one of the tasks of academic institutions is to educate better engineers, innovate and reform curricula, and make them relevant to industry practice.

The students' perceptions of the applicability of Lean principles in various key areas of the university are presented in [15]. The perceptions were analyzed based on the popular House of Lean model by Dennis [16]. The results of the study show a summary of key Lean activities and their relative importance as perceived by the students. Some of the identified wastes included: bad layout of faculty facilities, unequal teaching schedule, poor understanding of the curricula, inadequate communication between faculty and students, and improper management of facilities, resources, and inventory.

There have also been numerous authors dedicated to identifying the different types of waste and analyzing how to reduce or eliminate them in higher education. There are eight categories of waste for a manufacturing environment that were originally identified by Ohno [3].

Douglas et al. [17] presented a study regarding the eight wastes of Lean for HEI and some examples of each waste. Authors argue that the main types of waste in higher education are waiting and inventory. For example, waiting for an exercise to start, waiting for an educator to prepare his or her lecture or

his or her material, and students waiting for equipment that has to be moved from a different location. Moreover, they present some potential Lean solutions to the identified HEIs' wastes.

One of the goals of the research performed by Kang and Manyonge [18] is to understand that waste is at three main levels or fundamental blocks: Student, Research, and Staff. All three are complementary measures for the performance of any HEI. The implementation of a Lean-based structure can help an HEI to maximize the revenue, throughput, and customer satisfaction with high-quality products and minimize cost and waste. The results of removing waste in organizing, preparing, and performing the teaching process in a laboratory environment by adding value to student learning by using the 5S methodology are presented in [11].

Dinis-Carvalho and Fernandes [19] developed the Lean Teaching and Learning model based on the application of Lean concepts to teaching and learning in higher education. The model promotes continuous improvement on the basis of weekly feedback from students. Process and product evaluations are based on questionnaires to students, applied at the end of each class.

Simmons and Young [20] define and discuss specific higher education applications of three Lean principles: five why's, jidoka, and four waste categories. They propose how these principles can specifically be utilized to improve the student's academic experience using the vehicle of engineering student success centers. The authors consider two main stakeholders, the student as the customer who seeks true value from their educational journey and the institution's role in providing such value. Regarding the stakeholders in the higher education process, El-Sayed et al. [21] state that the government is the customer who initially funds education; however, the student is the primary recipient of the educational tuition service, and future employees in industry or society.

Imperial College London applied the Lean principles to a Software Engineering module to improve the way it was taught and thus prepare students for their future careers [22]. The lessons learned presented by the authors may be seen as very good recommendations for other lecturers, in any other discipline, looking to evolve their teaching structures and methods.

There have been many other specific initiatives related to the application of Lean principles or techniques that could be related, but more tangentially to the research presented in this article. Steinlicht et al. [23] describe how the manufacturing engineering technology program at South Dakota State University is using Lean production techniques to map the educational outcomes across the curriculum. The needs of the customer, or educational outcomes that provide value, are determined through surveys and interviews with constituents of the program.

Kruger [24] shows an application of Lean Thinking techniques in HEIs in South Africa related to the improvement of the administrative tasks to deal with a dual problem. On the one hand, HEIs do not receive funding from the government, and, to survive, they need students to enroll in their modules every year. To do this, it is necessary to carry out complex and slow administrative procedures, causing some students to drop out of the degree before completing it. This application of Lean allowed them to identify and propose improvements, such as ensuring that the communication channels are available to listen to and respond to the voice of the student.

The comparative study of Lean implementation in higher and further education institutions in the U.K. [25] can help to investigate and understand the differences that exist between educational institutions in the methods and practices employed in the development and implementation of Lean projects. Perhaps, the obtained results can help to translate the comparative to modules instead of to institutions. Authors have stressed that literature on Lean application in HEIs is still in its infancy, compared to the wealth of information on Lean in the production sector, however, the extent of this literature is still increasing.

Emiliani performed a study [26] based on the application of Lean principles and practices to the design and delivery of a graduate business module on leadership with the main objective of improving the quality and relevance of materials, eliminating waste, and delivering greater value as perceived by students. In [27] and [28], Emiliani stated that through small process changes, consistent with Lean principles and practices, faculty members could reduce teaching errors, ensure steady student workload and flow, and standardize curricular resources.

What has been described so far are some examples of the application of Lean Thinking to higher education. All the contributions have been useful to get ideas on how to apply the principles and practices of Lean Thinking to improve the Project Management module by eliminating waste and delivering more value to students.

Many authors agree that 21st-century educators are tasked with doing more with less, so the Lean philosophy is truly imposed as a logical solution for significant quality improvement while simultaneously reducing the wastes of higher education [29], [30]. There is still a lot of potential for improving value for students and eliminating waste at universities [31].

III. Phases of the Improvement Cycle

This section presents the different stages in the improvement method used to address the research goal: "to improve the value chain of the Project Management module to maximize the value that is provided to students by adapting and applying some of the Lean principles and techniques."

Value stream mapping is a Lean management tool that allows identifying, visualizing, analyzing, and improving all activities and materials required to deliver a service or product. In this case, we aim to teach the Project Management module. The ultimate goal of the VSM is to identify the waste in the value chain and try to remove it. The main benefits of this tool are that it allows working on the big picture, improving the whole, not just optimizing isolated actions; it allows the representation of the relationship between information and materials [31], [32]. The value stream mapping was used as a basis for achieving the objective of this research, to improve the Project Management module. This tool was chosen because the improvement of the

module has to be carried out as a whole, analyzing and improving all activities and materials, also referred to as resources.

Based on VSM, we established the following three different phases to detect and propose a set of improvements for enhancing the Project Management module.

1) *Phase 1. Identify and represent the value chain:* In this first phase, we first identified the essential activities that are carried out during the whole Project Management module (see Section IV-A), from the first session to the final mark. Second, all the resources (teaching materials, infrastructure, methodology, etc.) that are used to teach each of the activities were detected and collected (see Section IV-B). Finally, the value chain was represented using diagrams to easily visualize the resources of which it is composed (see Section IV-C).
2) *Phase 2. Analyze and review the value chain:* During the second phase, all the activities and resources that are part of the value chain were analyzed in depth. This analysis was performed by applying Lean principles and a set of techniques. The results obtained during this phase are described in Section V.
3) *Phase 3. Propose a new value chain:* The last phase consisted in describing the set of improvements that should be applied in the value chain of the module to eliminate waste. These improvements, which are presented in Section VI, are related to both the activities and the resources that will form part of the new value chain.

The authors' context, is the same as the authors described in [12]. "Project Management" is a mandatory third-year first-semester six European Credit Transfer System modules in the B.Sc. degree in computer science. The module was redesigned in the 2017–2018 academic year as a result of the findings obtained in the first part of this wide initiative. The student's satisfaction level regarding the new course design was analyzed during the academic years 2017–18 and 2018–19 and is presented in [12].

The study presented in this article was carried out during the 2019–2020 academic year. In total, 64 students participated, 55 male and 9 female students of similar age, ranging between 20 and 24 years. All students belonged to the same bachelor program, and thus they had comparable skills at the beginning of the course. The lecturers were the same as in the previous study.

At the beginning of the module, the participating students were asked to constructively criticize all aspects of the module, and at the end of the course, all their comments would be collected. As planned, during the last week of the academic year, the authors led and guided a retrospective session where the students questioned all the aspects of the module, from different perspectives. The list of activities and resources of the module to be analyzed was obtained after several cycles of refinement involving both students and lecturers.

IV. Phase 1. Identify and Represent the Value Chain

The purpose of the first phase is to identify and represent the value chain of the Project Management module, from the perspective of students.

An item brings value to a customer if it provides them with some positive benefit. Therefore, concerning the Project Management module, where the customers are the students enrolled in the module, everything that gives them value is directly linked to satisfactorily achieving the concepts and skills that are worked on during the module and the direct repercussion of this knowledge on the final grade.

The objectives that each student wants to achieve in the Project Management module are very personal and can vary. However, the most common goals we have identified are: passing the module with the best possible grade, understanding and achieving the concepts and skills that appear in the teaching guide, not having to dedicate more hours than estimated to practical exercises, and preparing for the exam, and having useful material that is explanatory and clear.

A. Four Stages of the Value Chain

The top-level value chain contains the stages and substages in which the module sessions can be grouped and, also, the resources or assets that are used in each one of these sessions, grouped by categories. Table I details the four stages and substages of the Project Management module.

These stages and substages were identified based on the current module design and from the perspective of all students taking the Project Management module during the 2019–20 academic year. This relationship begins on the day of the module presentation and ends when the grade appears in the academic record. "Presentation of the module and its planning" has been considered as a stage with its own entity and independent from the other three, because in such this kind of module, it is very important to offer detailed planning of the scope, contents, resources, and the different metrics that will be used to measure and assess the learning activities.

B. Resource Categories

The identification of the resources related to the Project Management module was done from the perspective of students and lecturers.

A great variety of elements were considered as resources. These resources are related to both infrastructure (the classrooms in which the sessions are taught, the necessary electronic devices, etc.), and the teaching materials, accessible from the university's online learning platform.

The identified resources were grouped into several categories based on similar characteristics. Table II details the categories used to group the resources.

C. Value Chain

The value chain of the module represents all the activities and materials, which were also referred to as resources. (graphically represented by boxes) that are used during the sessions or that support students to carry out the learning activities in each of the stages and substages (represented by circles) mentioned in Table I.

TABLE I
STAGES AND SUBSTAGES OF THE PROJECT MANAGEMENT MODULE

Stage	Sub-stage	Description
Presentation of the module and its planning	-	First 2-hours session during which the lecturers introduce the module, exposing its contents, objectives, and planning.
Learning of theoretical concepts	Conference "The Role of the Project Manager"	A 2-hours session given by a guest who is dedicated to Project Management.
	Project Management skills sessions	Two 2-hours sessions for introducing software tools for teamwork and for giving students a series of good practices for public speaking when presenting results.
	Teaching of theoretical sessions	Twelve 2-hours sessions during which lecturers teach the theoretical part of the module.
	Individual work	Individual and team tasks and study to be carried out by the students.
Development of the project	-	Twelve 2-hours sessions during which students, in teams of four members, present the partial results of their projects.
Assessment	Assessment of teammates	Activity carried out during the last session of the module so that students can evaluate their teammates by filling a form with some questions about motivation and performance.
	Project defense (50% of the module grade)	1-hour session (per team) during which the project and individual team member contribution are assessed.
	Exam	Last session where students are assessed with a theoretical exam to verify they have satisfactorily achieved the concepts worked on during the module.

TABLE II
RESOURCE CATEGORIES OF THE PROJECT MANAGEMENT MODULE

Resource category	Description
Infrastructure – Rooms and furniture	Areas and furniture to teach the sessions of the module, including classrooms, tables, chairs, etc.
Infrastructure – Supporting materials	Elements that facilitate giving lectures. They are used to support lecturers as they explain the syllabus or to contribute to student participation. Examples: projector, whiteboard markers, computers (of students and lecturers), etc.
Infrastructure – Supporting tools	Resources (not necessarily physical) that both students and lecturers should be able to use in order to teach or take the module. Examples: access to the campus wireless network, access to the online learning platform of the module, etc.
Infrastructure – Communication tools	Forums and messaging facilities available to students and lecturers to communicate with each other.
Online learning platform	Grouping and disposition of information, teaching materials, and assets in the online learning platform.
Human resources	People, not necessarily with the same role, who are actively involved in teaching the module.
Teaching materials	Assets used to support the explanation and learning of theoretical concepts. Examples: the teaching guide, the schedule, the estimated dedication of the students to the module according to its number of credits, slides to give the lectures, the PMBOK Guide, etc.
Examples	Assets provided by lecturers to expand or complement the concepts and issues discussed during the lectures.
Methodology	Methodologies and dynamics used to teach the sessions.
Session structure	Set of sections into which a session can be divided, according to what is carried out during it.
Assigned time	Number of hours/minutes assigned to each session or activity.

An expanded value chain has been developed for each of the four stages of the top-level value chain. Fig. 1 shows, as an example (the other three expanded value chains have been attached in the annexes), the one corresponding to the fourth stage "Assessment," together with its three substages: "Assessment of teammates," "Project defense," and "Exam." This value chain collects, for each resource category, the resources used to carry out the sessions or activities included in each of the three substages of the Assessment stage.

Fig. 1 shows resource categories depicted in yellow, and others depicted in purple. The ones in yellow represent materials and resources which have already been used during the first stage "Presentation of the module and its planning," such as the Rooms. The categories depicted in purple contain the resources that have been only used in the "Assessment" stage. For example, the Exam and Exam grades are specific to the substage "Exam." The same applies to the Question list, Project plans, and Delivery descriptions of the Project defense substage; or the Assessment form of the Assessment of teammates substage. The resources depicted in purple are not used in any other stage or substage.

V. PHASE 2. ANALYZE AND REVIEW THE VALUE CHAIN

Once the value chain was represented, an analysis of all the resources identified during Phase 1 was made to determine the value they bring to the students of the Project Management module. The authors applied the principles of Lean Thinking and Lean Development [33], to perform this analysis from many perspectives.

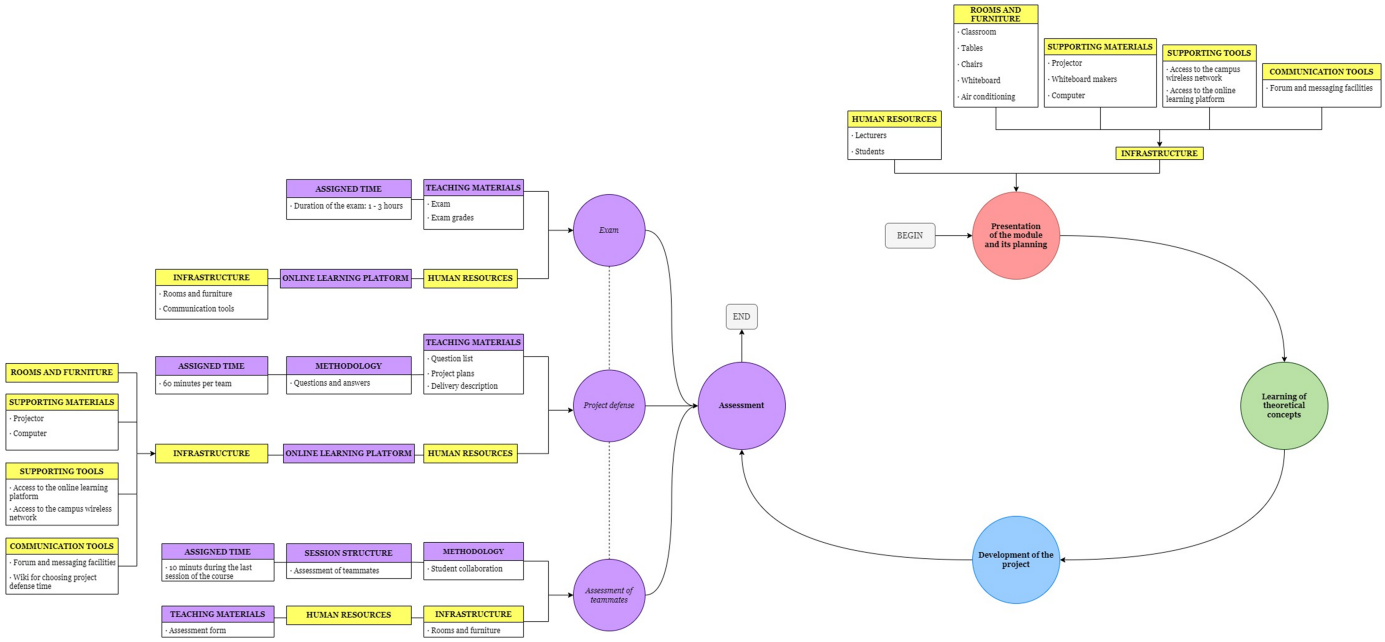


Fig. 1. Expanded value chain for the fourth stage "Assessment."

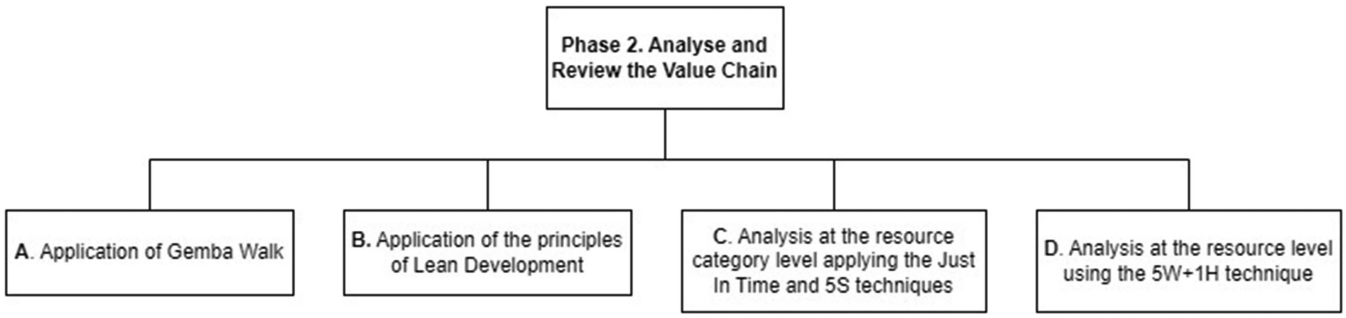


Fig. 2. Tasks of the value chain analysis.

The analysis of the value chain was divided into four tasks, which are described as follows and represented in Fig. 2.

1) Section V-A: the application of the Gemba Walk technique to collect information related to the Project Management module from the students' and lecturers' perspective.
2) Section V-B: application of the principles of Lean Development.
3) Section V-C: the analysis of resources at the resource category level applying the Just in Time and 5S Lean techniques.
4) Section V-D: the analysis of resources at the resource level using the 5W+1H technique.

A. Application of Gemba Walk

The Gemba Walk is a Lean technique that implies being in the place where the value is created and observing everything. During the analysis of the value chain of the Project Management module, the Gemba Walk consisted in questioning everything that was related to the module. It was performed from the following two perspectives regarding the two roles more closely related to the learning process.

1) From the students' perspective, involving all the module students of the 2019–2020 academic year. The initial result of the Gemba Walk was elaborated, reviewed, expanded, and agreed upon by all the students who participated in the study and was led by the main author of this article, when taking the module as a student.
2) From the lecturers' perspective, involving the rest of the authors.

The Gemba Walk can be seen as the great umbrella that encompasses the performance of the detailed analysis that allowed to collect, organize, and analyze all the information on the activities and resources used to carry out all the module sessions. The outputs of these analyses are described in the following sections (see Sections V-B–D).

B. Application of the Lean Development Principles

The seven principles of Lean Development [33] were applied to analyze whether there is waste or rejection in any of the stages of the value chain and to identify possible improvements. The following sections detail its application to the Project Management module.

1) Eliminate Waste (Muda): In Lean Thinking, any activity that consumes resources but does not add value to the customer is considered a waste (or *muda* in Japanese). This research has analyzed the wastes related to the way of teaching the Project Management module from the following eight different points of view.

1) *Overproduction:* In the teaching environment, overproduction means an excess of information aimed at students. In our study, it would consist in introducing concepts that were not foreseen in the syllabus or that are not specific to the module. This waste was not detected in our case.
2) *Excess inventory:* It is considered that students have excess inventory when they have more material than they need to understand the different concepts, solve the problems that are proposed and pass the course with the highest grade. Materials those are not essential for students at that time, but that lecturers make available to expand concepts or for use in a future professional, are examples of this *muda*, as these extra materials cause unnecessary access, reading, and extra comprehension efforts to be made. It was detected that some documents available in the online learning platform could be omitted and removed.
3) *Waiting:* This waste refers to the students having the necessary material at the right time without causing delays in the start of the activities to be carried out. No waiting for learning materials were detected, as they were being delivered before or just after each session. In this way, students could start doing the work as soon as they wish, without having to be aware of the needed material.
4) *Unnecessary movements:* All the additional actions that students must take to access or process the information they need to carry out the tasks of each stage are considered unnecessary movements. It was detected that the movements (clicks) that students should make to access the materials available in the online learning platform could be optimized.
5) *Inefficient transportation:* All documents to be exchanged between students and lecturers could be considered transportation. A waste of inefficient transportation would occur when this exchange is not necessary or when the effort of this exchange could be reduced. Both the material that lecturers make available to students and their results are uploaded to the online learning platform. Perhaps this exchange could be optimized, which would consist in improving the functionality of the platform.
6) *Reworks:* This waste refers to the additional work that students have to do to correct problems due to defects or errors in their projects. Reworks in the development of the project were detected, as this project is developed following an incremental life cycle. Then, students should make changes or rework almost weekly. The lack of examples or detailed information about the expected results also caused reworks.
7) *Overprocessing:* In the case of our Project Management module, over-processing occurred when students developed more results or products than the ones that were needed. Students have a list of deliverables and a rubric with the criteria that will be used to assess the work done. Therefore, cases of this waste do not usually occur.
8) *Nonutilized talent:* At no time were the inappropriate resources devoted to performing inappropriate functions and tasks, as when lecturers are assigned to the module, the lecturer profile that best suits the module needs is chosen. The existence of non-utilized talent for teaching the Project Management module was not detected.

2) Amplify Learning: Amplify Learning means to increase the ability of a team to learn anything quickly and effectively. In the scope of the Project Management module, this principle is applied in the practical sessions in which the students' projects are monitored and controlled. During these sessions, lecturers and students give their opinion and provide feedback on what it has been presented, criticizing the results constructively. At the same time, each team self-criticizes to improve their own project. We could say that students learn constructively from their own projects, from the projects of their classmates, from their own successes and mistakes, and from those of their classmates. Therefore, we can say that this principle is already effectively applied.

3) Decide as Late as Possible: The third principle is based on postponing decision-making while gathering information to assess which is the best option to choose. This principle does not apply to the Project Management module, as the decisions made by students must be adjusted to the milestones set by the lecturers to ensure that the planning of the module is respected.

4) Deliver as Fast as Possible: This principle refers to the team's desire to deliver the work it is doing to provide value to customers as soon as possible.

For the Project Management module, during the third stage of the value chain "Development of the project," the members of each team agree on the tasks to be performed by each of them. In this way, the work becomes self-directed and self-organized at the team level. This fact is directly related to the accomplishment of the assigned tasks with greater involvement of the students, being more productive, and being able to deliver the results before. Although it is not usual for students to deliver before the indicated date, some reward could be considered for those who do.

5) Empower the Team: This principle applies to all aspects of the operation of Lean teams, from how they communicate, how they manage conflicts, or how they improve processes, among others. Lean teams can foster respect for people and empower the team through self-determination, motivation, leadership, and expertise.

While taking the Project Management module, it was possible to check that during all the stages of the value chain, the lecturers fostered the self-determination of the students, encouraging them to develop their projects and elaborate their own work

procedures. The lecturers offered their support during the whole semester for the teams to achieve these results.

During all the module sessions, students are encouraged to participate and share their thoughts. This fact fosters a sense of belonging to the group and allows for the achievement of skills, best practices, and discipline. Besides, it allows students to be aware of the significant advances that have been made in the learning of theoretical concepts and other soft skills (such as communication), through the support, criticism, and advice received from lecturers and other teammates.

6) Build Integrity in: This principle refers to periodically reviewing the work being done, and the results obtained, to identify possible improvements to obtain a final product of higher quality. The principle promotes the performance of work in small iterations to get constant feedback and make continuous improvements.

In the case of the Project Management module, the work carried out during the practical sessions was very positively valued. The method followed allows students to obtain opinions regarding their project and use this feedback to improve it until achieving the desired or required quality level.

7) Optimize the Whole: This principle consists in considering the system as a complete set or unit instead of considering it as small components or activities. Concerning the Project Management module, it was verified that during the semester, the concepts learned and applied during this module are closely related to those corresponding to other modules in the degree in computer science. The project that is carried out throughout the module is based on the creation of a project plan, containing the work packages and activities of any software development: analysis, design, implementation, testing, etc., topics that are studied in the other modules of the degree.

C. Analysis at the Resource Category Level

The analysis at the resource category level was based on the application of some Lean techniques to all the resource categories of each of the four stages of the value chain. More concretely, Just in time and 5S were used.

1) Just in Time: Just in time means that customers can have what they need at the right time, in the right place, with the exact quantity and quality required.

This technique was applied to analyze if students are properly provided with the resources of each of the stages and substages of the value chain. As an example, Table III shows the analysis of Just in time for the resource category "Teaching materials." The goal was to determine if the materials detailing the concepts the students need to develop their project during the third stage of the value chain "Development of the project" are at their disposal at the right time, in the right place, with the exact quantity, and with the required quality.

The analysis of the category of resources "Teaching materials" allowed us to identify that the slides and other materials to develop the project are delivered at the right time, with the exact quantity and the quality required. The just-in-time technique helped to analyze whether the resources were located in the right place.

TABLE III
ANALYSIS OF JUST IN TIME FOR THE RESOURCE CATEGORY "TEACHING MATERIALS"

Resource category:		**Teaching materials** Assets used to support the understanding of the concepts and the development of the project.
Stage in the value chain:		3. Development of the project
Just in time items	*Right time?*	Yes. The necessary materials (templates and examples) to develop each project part are available to students from the day in which the related theoretical concepts are taught.
	Right place?	No. To develop the project it is necessary to use the materials of the theoretical sessions (slides and project guidelines) that are located in another section of the online learning platform.
	Exact quantity?	Yes. The needed teaching materials are made available with the exact amount to undertake each project deliverable.
	Quality required?	Yes. The contents of the resources are useful, explanatory, and clear enough to carry out the assigned tasks.

Using the same procedure, the resource categories belonging to each stage and substage of the value chain of the Project Management module were analyzed.

2) 5S: 5S refers to five Japanese terms used to describe the steps of the 5S system of visual management. Each term starts with an S. In Japanese, the five Ss are *Seiri*, *Seiton*, *Seiso*, *Seiketsu*, and *Shitsuke*. In English, the five Ss are translated as Sort, Set in Order, Shine, Standardize, and Sustain. The purpose of this technique is to achieve continuous improvement by documenting the best practices that are currently being applied, to be able to establish a baseline on which to propose and apply the improvements.

The 5S were used to assess the resources which are used in each of the stages and substages of the value chain. As an example, Table IV shows the evaluation of the 5S for the resource category "Infrastructure—rooms and furniture," used during the practical sessions in the third stage of the value chain "Development of the project." The goal was to determine whether the infrastructure used for these sessions needed any change.

The analysis carried out applying the technique of the 5S to the resource category "Infrastructure - Rooms and furniture," allowed us to determine which requirements should be met so that the students can carry out the group sessions comfortably, how to act in case they are not met, and how this new way of conducting group sessions should be sustained.

D. Analysis at the Resource Level

The work at this level was based on analyzing all the elements that are part of the value chain by using the 5W+1H technique. The purpose of this analysis was to know the current state of all the teaching materials, resources, and methodologies applied in each session.

TABLE IV
ANALYSIS OF 5S FOR THE RESOURCE CATEGORY "INFRASTRUCTURE—ROOMS AND FURNITURE"

Resource category:		**Infrastructure - Rooms and furniture** Areas and furniture to teach the sessions of the module, including classrooms, tables, chairs, etc.
Stage in the value chain:		3. Development of the project
5S	*1. Sort (Seiri)*	It is necessary that the tables and chairs in the classroom can be moved easily.
	2. Set in order (Seiton)	Tables and chairs should be able to group so that team activities can be carried out comfortably.
	3. Shine (Seiso)	Request a change of classroom if the one assigned does not meet the requirements for moving tables and chairs.
	4. Standardize (Seiketsu)	Check that the classroom assigned to the practical sessions has tables and chairs that can be moved.
	5. Sustain (Shitsuke)	At the beginning of each session, students will need to group the tables and chairs so that all members of the team have adequate visibility of the digital screen and the whiteboard.
Suggestions/ Improvements:		It would be better to have a room equipped to facilitate teamwork.

The 5W+1H technique involves using the questions *What?*, *When?*, *Where?*, *Who?*, *Why?*, and *How?* to know in depth a process or problem. This technique was used to analyze all the information related to the module from many different points of view. Table V shows an example of an evaluation matrix that collects the questions raised related to the "Methodology of the project defense: questions and answers," a resource that belongs to the fourth stage of the value chain "Assessment," represented in Fig. 1.

TABLE V
ANALYSIS OF 5W+1H FOR THE RESOURCE "METHODOLOGY OF THE PROJECT DEFENSE: QUESTIONS AND ANSWERS"

Resource category:		Methodology
Stage in the value chain:		4. Assessment
Sub-stage in the value chain:		Project defense
5W+1H of Kaizen	*What?*	What is done during the project defense? What are the questions asked during the project defense? What resources and materials can the students use during the project defense?
	When?	When is the material to be defended delivered? When is the date and time of the project defense communicated? When are the results of the project defense published?
	Where?	Where is the date and time of the project defense communicated? Where does the project defense take place? Where are the results of the project defense published?
	Who?	Who participates during the project defense? Who prepares the questions? Who asks the questions? Who sets the defense dates and times? Who is asked to answer each question?
	Why?	Why should there be a project defense? Why is the project defense mandatory? Why is the project defense assessed?
	How?	How are the project defense dates and times established? How is the project defended? How are the questions? How should the answers be given? How is the defense assessed? How can be the project defense grade reviewed?

VI. PHASE 3. PROPOSE A NEW VALUE CHAIN

Based on the analysis carried out and presented in Section V, a set of improvements that contribute to remove elements that do not add value to students was identified. These improvements are related to both the learning activities and resources. Once these improvements have been applied, a new improved version of the value chain of the subject will be obtained.

The proposed improvements will have to be grouped according to the stage and substage in the value chain, and the resource category to which the resource to be improved belongs. An initial grouping of the improvements that:

1) the resources used during the *Presentation of the module and its planning stage*;
2) the activities and resources used during the *Learning of theoretical concepts* stage (including its substages);
3) the generic elements, which are used in various stages and substages of the value chain of the module;
4) the resources used during the *Development of the project* stage; and
5) the activities and resources used during the *Assessment* stage (including its substages).

In this article, for space reasons, only the improvements related to the stages of the value chain that have been analyzed and shown in the former sections are detailed. However, the global set of improvements resulting from the research carried out is much broader, as it covers all the stages and substages described in Table I and the resources of all the categories described in Table II.

The improvements that were selected to be implemented are detailed below. The selected improvements required the least effort on the part of the teachers to generate or modify the assets. These improvements do not require changes in furniture or infrastructure, nor the completion of administrative procedures. These improvements are described in Section VI-A and, analogously, some of the improvements related to changes in resources are described in Section VI-B.

A. Changes in the Value Chain Activities

1) *VCA1:* Modify the way of accessing some materials of the online learning platform, detected during the analysis of *Unnecessary movements*.

2) *VCA2:* Improve the functionality of the online learning platform so that the exchange of documents between lecturers and students is more efficient.
3) *VCA3:* Describe any reward for students who deliver before the deadline and encourage *Deliver as fast as possible*.
4) *VCA4:* From the analysis of the "*Methodology of the project defense*" by using the 5W+1H technique, it was possible to wonder about every detail of the methodology used to defend the project. The following improvements regarding this activity were identified.
   - The "*Defense hours*" must cover morning and afternoon hours, and they must be announced in advance. Then, the lecturers will prepare a wiki with all the possible defense hours for every team to choose the best option for all the members. This wiki will be available six weeks before the project defense.
   - The project defense grade should be individual. Then, this grade will not be the same for all the team members.
   - The weight of the project defense grade will be 50% of the grade of the whole module.

B. Changes in the Value Chain Resources

1) VCR1: Eliminate some of the resources that are seen as unnecessary and that have been identified as examples of the *Excess inventory* muda.
2) VCR2: Improve the document that details the work that students must undertake each week, so that it is clearer and reduces rework.
3) VCR3: Provide more detailed rubrics for the same purpose.
4) VCR4: The analysis of Just in time for the resource category "*Teaching materials*" made it possible to detect that a redistribution of the materials needed to carry out the project would bring more value to students, as they could access these resources more efficiently. As a result, the contents of the online learning platform will be redistributed.
5) VCR5: From the analysis of the "*Methodology of the project defense*" by using the 5W+1H technique, different improvements related to the resources used during this activity were detected.
   - Provide students with a list of sample questions that could be asked during the project defense.
   - Establish a clear set of indicators, and their expected values, to assess the project defense.
   - Develop an assessment rubric to score different items during the project defense.

VII. Assessment of the Implementation of Improvements

During the 2022–23 academic year, the improvements mentioned in the previous section were implemented. To measure the benefits derived from the implementation of the improvements, a set of indicators was defined. These indicators, briefly described in Table VI, aim to evaluate the improvements in activities and resources of the value chain.

TABLE VI
Indicators to Assess Improvements

Indicator	Description	Improvements assessed
M1	Number of doubts related to the Teaching Materials raised in the forum of the Online Learning Platform.	VCA1, VCA2, VCR2
M2	Number of projects delivered one day before the due date.	VCA3
M3	Degree of student satisfaction with the project defense. *This data will be collected from the module retrospective.*	VCA4
M4	Number of tutoring sessions per student.	VCR2
M5	Number of students who passed the defense of the project.	VCR5

VIII. Conclusion and Future Research

In 2015, the authors started research aimed at improving a Software Project Management module in computer science from as many perspectives and covering as many aspects as possible. In [12], Mas et al. redefined the course and different management supportive assets were created. That version of the course was validated during two academic years (2017–18 and 2018–19). During these two years, the student perception of Software Project Management was measured by analyzing four different aspects: student's learning perception, attitude toward Software Project Management, complexity perception, and student performance.

On this occasion, the research has been aimed at analyzing the student's perception from the point of view of the value provided by the different activities of the teaching process and the resources used throughout it. This work has applied the principles of Lean Thinking from the perspective of the client, that is, the students of the module. The analysis has favored the participation of alumni, who are the key stakeholders of the entire learning process. Constant collaboration with students has been instructive regarding the detection of weaknesses and wastes and thus helped lecturers to objectively identify key improvements for the benefit of future students.

The results obtained have permitted us to observe that the application of the principles of Lean Thinking to detect wastes and identify possible improvements is not only possible but also of great interest. This research has helped us to appreciate the many benefits of their implementation: the ease of identifying waste that went unnoticed, or the initiation of small activities that, although seemingly insignificant, can aid the organization in becoming more efficient and focusing on value-based activities. It is not always easy to objectively analyze the day-to-day work from different perspectives to propose feasible improvements.

The authors have been surprised that it has been possible to analyze the value chain from so many perspectives. Also, a large number of improvement proposals are suggested by the students. The lecturers of the module under study thought that all the structure, the contents, and the resources used had been

significantly improved in the previous iteration. They did not imagine that there was still so much room for improvement.

The authors hope that this experience will encourage other lecturers to introduce Lean principles into their teaching management. Furthermore, the application of Lean techniques will generate changes that are useful to both the lecturers and the students taking their modules.

We continue working to expand this research and we do it in three very different research lines. The first research line would consist in drawing up an action plan offering a guide to implement the new value chain with all the identified improvements. The first step will be to assess the impact of each improvement. Then, the aim will be to prioritize the improvements depending on the feasibility of carrying them out. The assessment of the improvements will be made by analyzing the impact that their application may have from the following perspectives.

1) *Necessary effort to implement the improvement:* The effort in hours that lecturers will have to dedicate to be able to prepare and apply the improvement. It can consist in developing new teaching materials or modifying the current ones, and reorganizing the online learning platform, among others.
2) *Economic effort:* The amount of money to be invested to implement the proposed improvement.
3) Wait time to apply the improvement. The amount of time it takes to get approval to apply the improvement.
4) *Benefits for students:* A set of benefits that the improvement can bring to students.

To prioritize improvements, a set of criteria will be defined to calculate the total impact that can be derived from the application of each improvement.

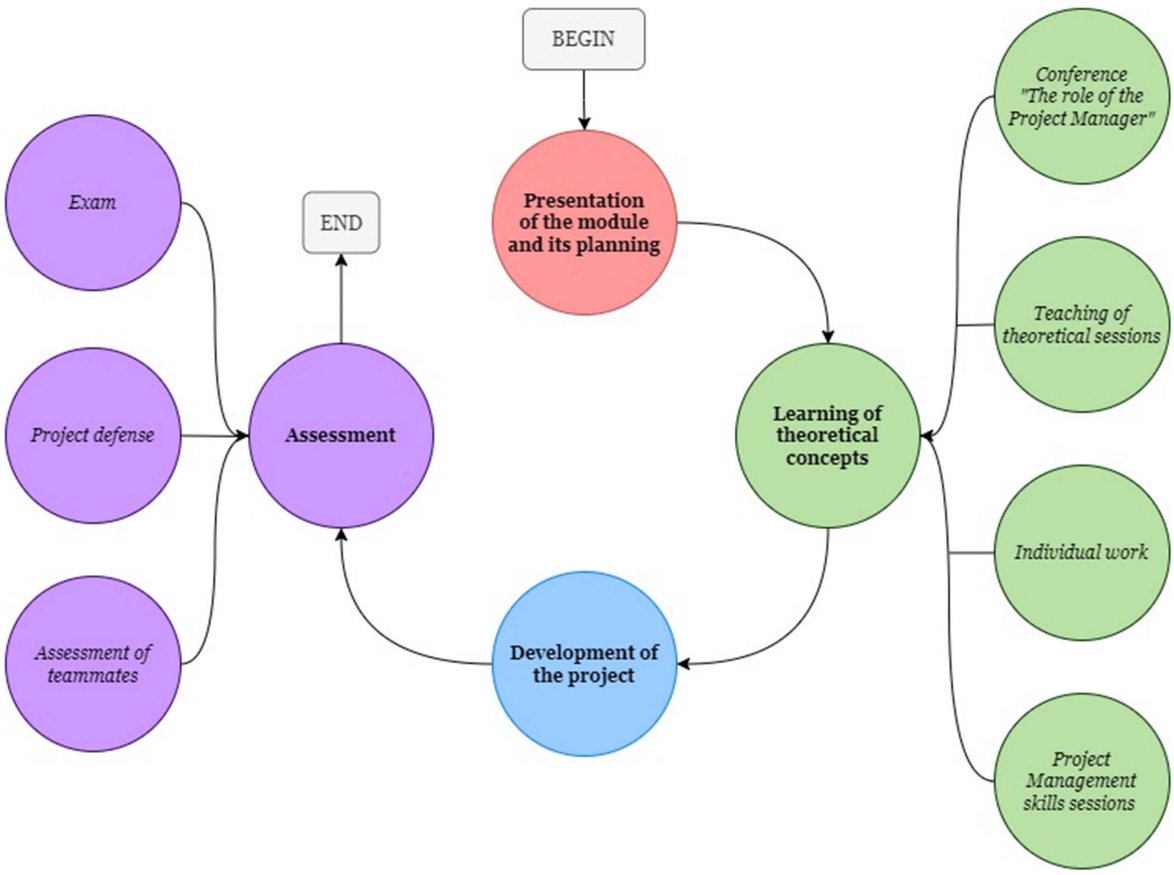
The second research line would consist in applying these improvements and validating the result during an academic year. Based on the previous results, the aim will be to implement the new value chain considering all the improvements identified and prioritized.

The third research line is related to our trajectory in the process improvement area. We are working on the definition of a generic teaching process reference model based on the ISO/IEC/IEEE 24774 standard [34] for process description, which is also assessable according to the series of standards ISO/IEC 33000 for process assessment [35].

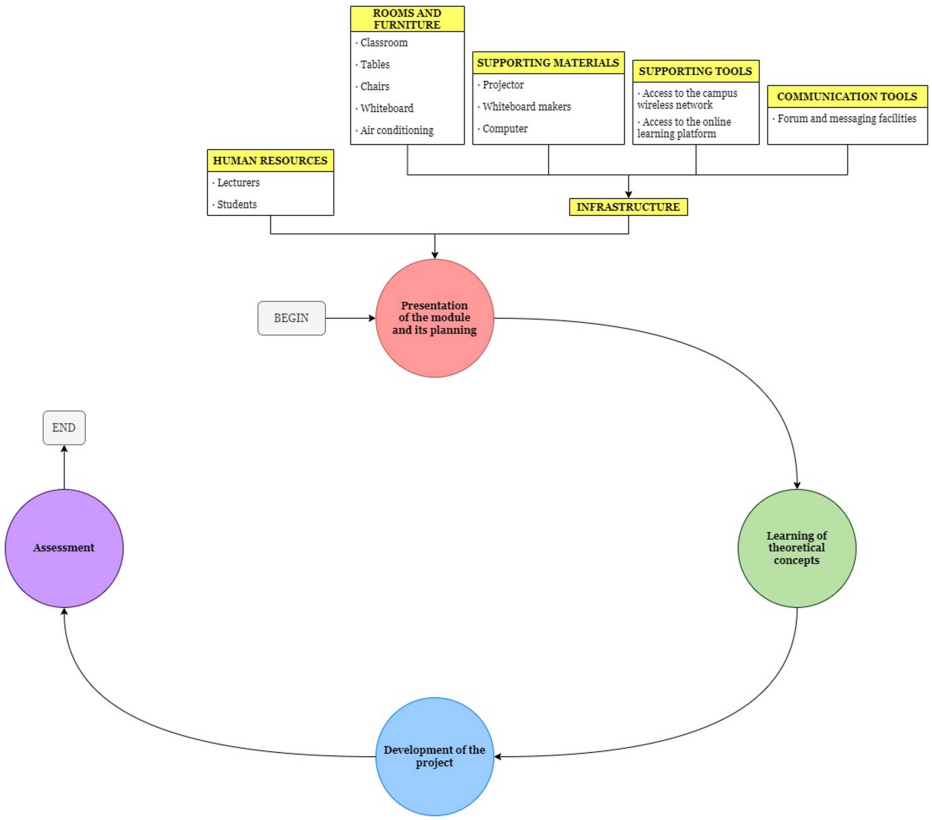
Appendix

This section presents the value chain diagrams mentioned in Section IV.

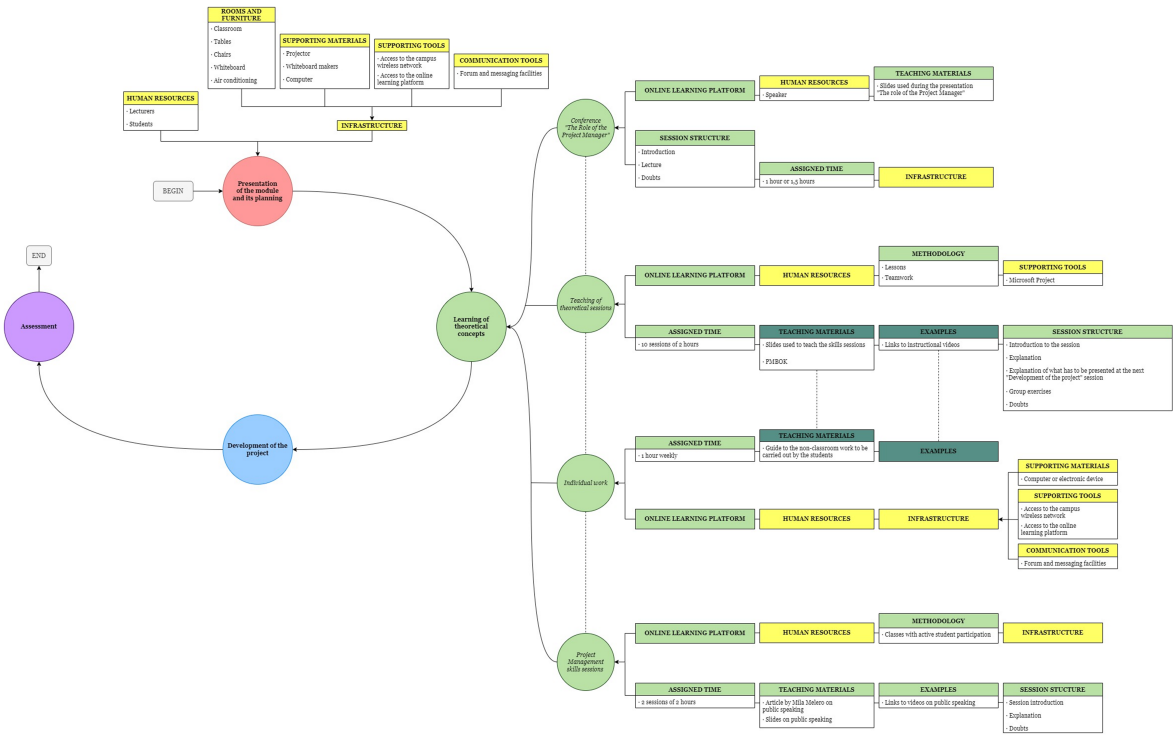
A. Value Chain Diagram



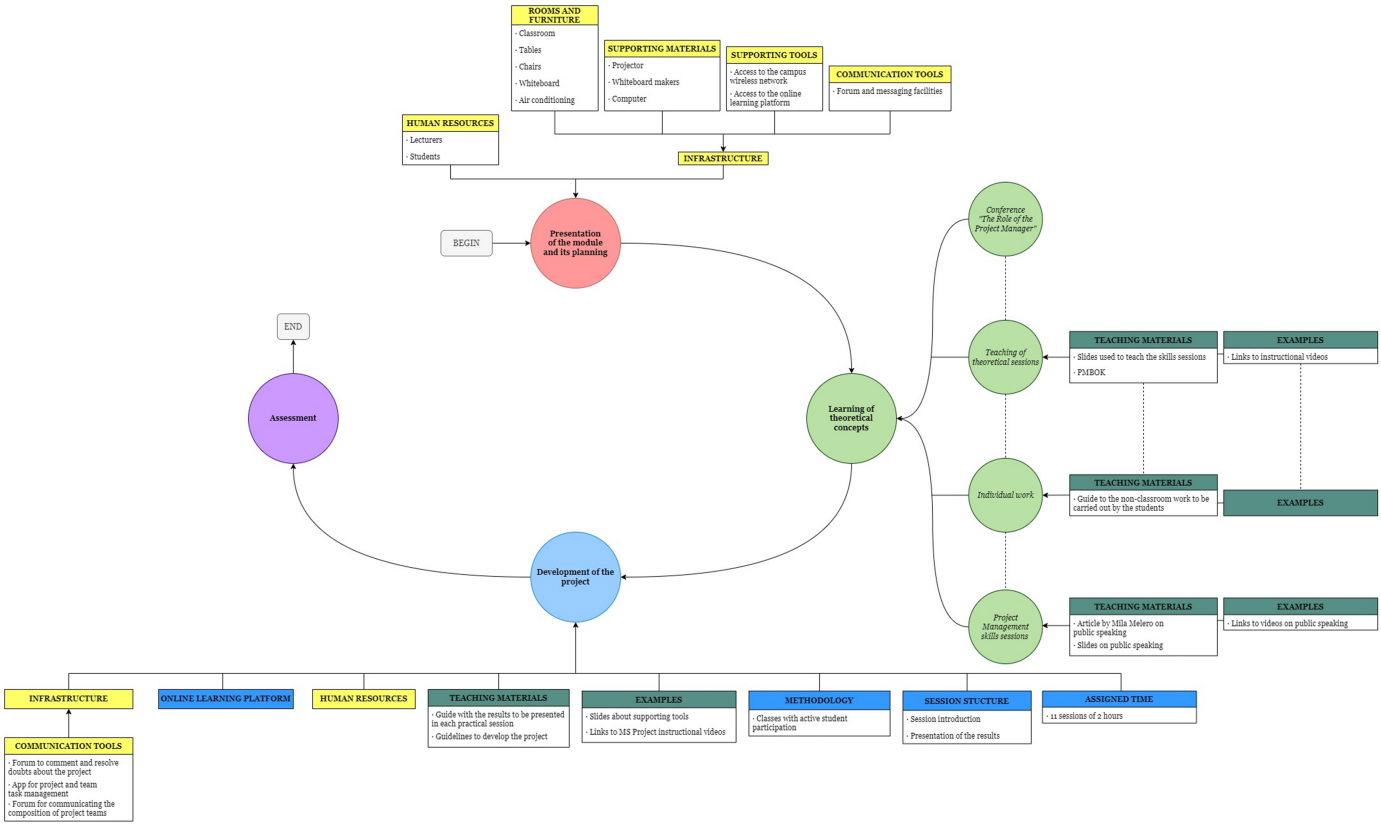
B. *Value Chain Diagram of the Presentation of the Module and Its Planning the Stage*



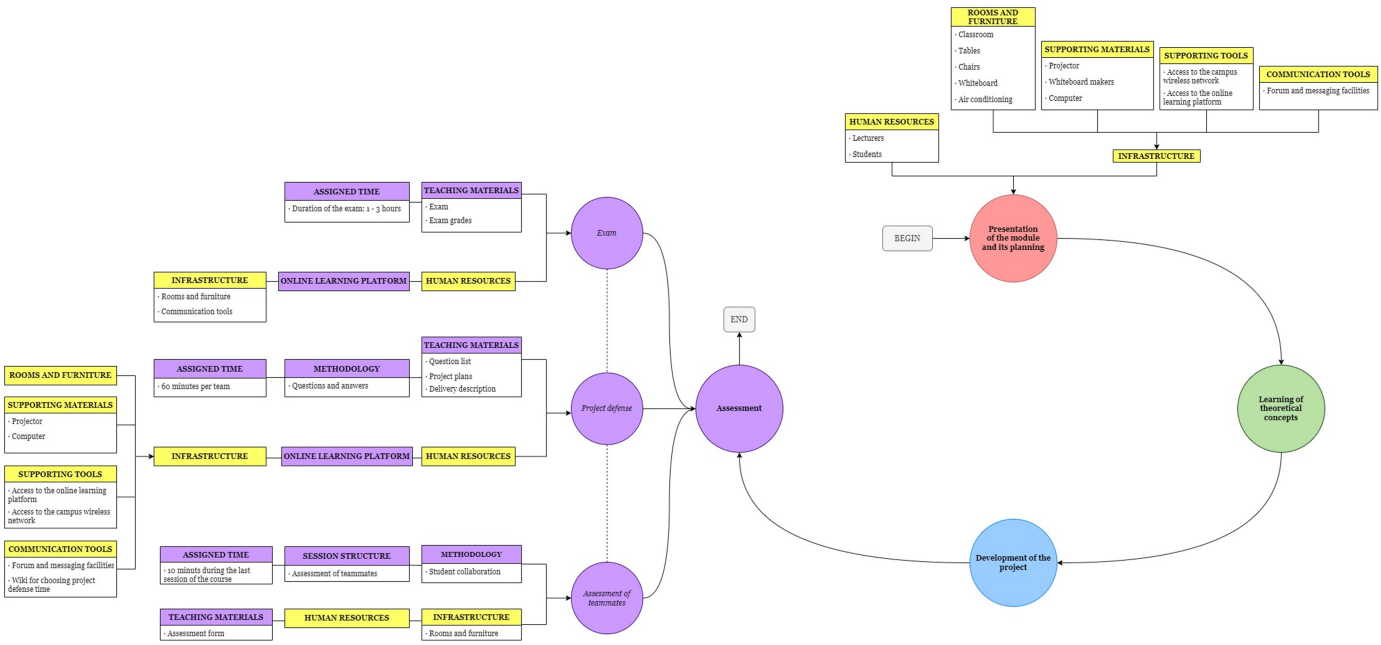
C. *Value Chain Diagram of the Learning of Theoretical Concepts Stage*



D. Value Chain Diagram of the Development of the Project Stage



E. Value Chain Diagram of the Assessment Stage



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